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In this issue

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Hartford's famous Charter Oak which flourished for 200 years before it fell in 1856

LIST OF ADVERTISERS

Directory of Professional Services—pp. 25-29

COMING MEETINGS

September **12–14**—Minnesota Section at Hotel Nicollet, Minneapolis. Secretary: Leonard N. Thompson, Gen. Mgr., Water Dept., St. Paul 2, Minn.

13–14—New York Section at Whiteface Inn, Whiteface. Secretary: R. K. Blanchard, Vice Pres., Neptune Meter Co., 50 W. 50th St., New York, N.Y.

17–19—Kentucky-Tennessee Section at Louisville Kentucky Hotel, Louisville. Secretary: R. P. Farrell, Director, Div. of San. Eng., State Dept. of Public Health, 420—6th Ave., N., Nashville, Tenn.

19–21—Michigan Section at Whitcomb Hotel, St. Joseph. Secretary: T. L. Vander Velde, Chief, Section of Water Supply, State Dept. of Health, Lansing 4, Mich.

19–21—Pennsylvania Section at Bellevue-Stratford Hotel, Philadelphia. Secretary: L. S. Morgan, Div. Engr., State Dept. of Health, Greensburg, Pa.

24–25—Rocky Mountain Section at Hotel Cosmopolitan, Denver, Colo. Secretary: George J. Turre, San. Engr., Board of Water Comrs., Box 600, Denver, Colo.

24–26—Alabama-Mississippi Section at Buena Vista Hotel, Biloxi, Miss. Secretary: Charles W. White, Asst. San. Engr., State Dept. of Public Health, 537 Dexter Ave., Montgomery 4, Ala.

25–27—Wisconsin Section at Pfister Hotel, Milwaukee. Secretary: Leon A. Smith, Supt., Water & Sewerage, City Hall, Madison 3, Wis.

27–28—Ohio Section at Commodore Perry Hotel, Toledo. Secretary: F. P. Fischer, Sales Engr., Wallace & Tiernan Co., 812 Perry Payne Bldg., Cleveland 13, Ohio.

Sept. 30–October 2—Missouri Section at Hotel Robidoux, St. Joseph. Secretary: Warren A. Kramer, Div. of Health, State Office Bldg., Jefferson City, Mo.

Journal

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July 1951

Vol. 43 • No. 7

Contents

Departments

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Journal

AMERICAN WATER WORKS ASSOCIATION

VOL. 43 • JULY 1951 • NO. 7

Studies on Diatomaceous Earth Filtration

By Joseph M. Sanchis and John C. Merrell Jr.

A paper presented on May 1, 1951, at the Annual Conference, Miami, by Joseph M. Sanchis, San. Engr., and John C. Merrell Jr., San. Eng. Assoc., Dept. of Water and Power, Los Angeles.

CLIMATIC and environmental conditions in the Los Angeles area have led to the development of plankton growths in the series of large, open, distributing reservoirs that supply the city (Fig. 1). These growths and their subsequent decay create occasional taste and odor problems, and to a large extent they constitute the load of suspended matter that the water carries into the distribution system.

Constant efforts are therefore put forth to control biological activity in reservoirs by chemical treatment. As a result, the quality of the impounded water is such that chlorination alone conditions it to meet the present U.S. Public Health Service drinking water quality requirements. Consequently, a water filtration program for Los Angeles is not being considered at this time. The Division of Sanitary Engineering has nevertheless been authorized to gather data which will permit selection of the most effective and economical process for the treatment of the city's supply if additional treatment facilities be required in the future.

The work done on diatomaceous earth filtration is part of the general program of such water treatment studies.

Treatment Problem

About three-fourths of the Los Angeles population resides south of the Santa Monica Mountain Range, an east-west barrier which divides the city into two sectors of approximately equal areas. Most of this section of the city is served water from three distributing reservoirs located in narrow canyons along the range.

When water treatment studies were started, it seemed logical to consider filtration at the outlets of reservoirs serving only the southern section as the most profitable water treatment investment. Closer investigation, however, revealed that filtration at the out-

lets of these reservoirs presented two serious problems.

The first difficulty was the lack of sufficient space. A conventional gravity type plant of sufficient capacity to treat the flows expected from Hollywood Reservoir in the near future has been estimated to require 3.5 acres. The topography of the plant site, however, presents less than 1 acre that could be utilized for this purpose. Similar limitations exist at the outlets of both Stone Canyon and Franklin Canyon Reservoirs, the other two distributing points serving the southern section.

The other problem presented by conventional gravity type rapid sand filters is that they would dissipate all the available head at the lowest usable gate elevation in the reservoir outlet tower, without considering the head loss necessary to put the water through the plant. It would therefore be necessary to pump an appreciable portion of the filtered water in order to regain the head needed to supply the foothill areas.

Under the circumstances, it seemed that the most practical means of obtaining the required water quality, within the existing space and preferred head loss limitations, was offered by the adaptation of diatomaceous earth (diatomite) filters to large-scale operation.

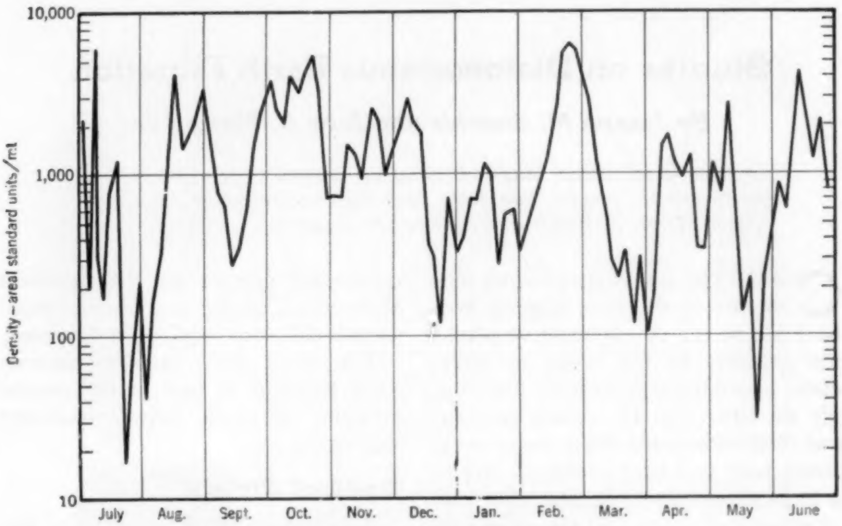

Fig. 1. Reservoir Water Quality Variations

Typical variations in reservoir water quality are reflected by fluctuations in microscopic plant densities, expressed in terms of areal standard units per milliter.

The basic feature of the diatomite method of filtration is the use of a rigid, permeable membrane that supports a layer of filtering medium of diatomaceous silica or similar material, commonly called "filter-aid."

Inasmuch as the layers of filtering media are very light and can be supported on a vertical filter element membrane by any flow of raw water

through the filter, it is possible to filter horizontally instead of vertically as in conventional sand and gravel filters. Horizontal filtration, coupled with the fact that the diatomite process lends itself to the treatment of the local water supply without preconditioning in coagulation and settling basins, make possible a great saving in space.

Diatomite and similar filters have been used in industrial processes for many years to clarify liquids at very low filtration rates. More recently, diatomite filters have been used successfully to filter military water supplies in the field (1) and to clarify swimming pool water (2). In all these applications, however, the volumes of water treated were relatively small.

Although considerable data on diatomite filters were on hand as a result of research carried on by the Water Supply Equipment Branch of the U. S. Army Engineer Board and by equipment manufacturers, there was no precedent to follow for designing a water filtration plant of the magnitude required for treating the outflows from the department's main reservoirs. It was therefore obvious that a local study was necessary to determine the applicability and limitations of the diatomite process on the basis of its performance with the city's water supply, and to obtain more complete information on all factors affecting design and operation.

Diatomite Process

The filter-aid ("diatomite") process is essentially a physical or straining method of filtration. The complete cycle of this process is:

1. *Precoat Operation.* During the first, or precoat operation, a layer of filter-aid is built up on the septa of the filter elements. (The septum is the permeable portion of the filter element assembly which actually supports the filter-aid.)

2. *Service Flow.* During the service flow, actual filtration takes place until a predetermined head loss is reached.

3. *Backwash.* In backwashing, the fouled filter-aid is expelled from the filter elements.

4. *Drain-Down.* During drain-down the water in the filter shell containing the backwash sludge is released.

There are two procedures in general use for applying the precoat on filter elements. In one method, the filter-aid is inserted directly into the filter shell and is brought to the filter elements by the water being filtered, at the start of the filter run. In the other precoating procedure, used in most of this experimental work, a prepared filter-aid slurry is recirculated through the filter until the filter effluent returning to the slurry tank is clear.

The porosity of the filter element septum and the fineness of the filter-aid used will determine, to a large extent, the selection of precoating procedure.

The recirculating procedure is used to advantage when dealing with a large opening filter element septum and fine filter-aids, in order to avoid the presence of fine particles in the effluent at the start of the filter run.

Under normal circumstances the precoat cake surface becomes fouled with a layer of particles removed from the water being filtered. The rapidity with which this fouling takes place depends chiefly on the porosity of the filter-aid, the type and amount of suspended matter in the water being filtered, and the filtration rate used.

Slimy material, large concentrations of green and blue-green algae, and close-textured diatoms have been found

to have a marked shortening effect on filter runs. Turbidity resulting from more than 20 ppm. of silt has also been troublesome. Although partial removal of turbidity by flocculation and sedimentation prior to filtration may be helpful, the studies indicate that any fine floc reaching the filter will tend to seal the filter-aid, thereby shortening the filter run. The need for additional structures in which to carry on flocculation and sedimentation will also increase space requirements as well as the cost of the diatomite plant. As a result, of course, some of the advantages of the process over conventional rapid sand filtration would be diminished.

The surface fouling of diatomite filters is materially lessened, and the length of filter runs consequently increased by the continuous injection of small amounts of filter-aid into the raw water as it enters the filter. The action of this filter-aid addition, called "body feed" is to prevent the matter suspended in the water from forming a continuous film over the entire filter cake surface.

Pressure conditions in most of the Los Angeles foothill areas are such that if any head is lost at the filters, additional pumping will be necessary to maintain the required pressures in these areas. It was therefore decided to conduct filtration studies at maximum pressure differentials of 10 psi., with a sufficient number of runs extended to 20 psi. to determine differences in yield and length of run.

Commercial Filter Studies

The first experimental work was carried out using three commercial filters, two of which were upward-flow units equipped with metallic filter elements. The arrangement of the filter elements and some of the operating features of these two filters differed, but in filter area and type of filter element they were identical. The third filter varied radically in design from the others and could be operated with either porous stone tubes or cylindrical metallic screens. A fourth commercial filter unit offering 30 sq.ft. of filter area was procured, and was equipped

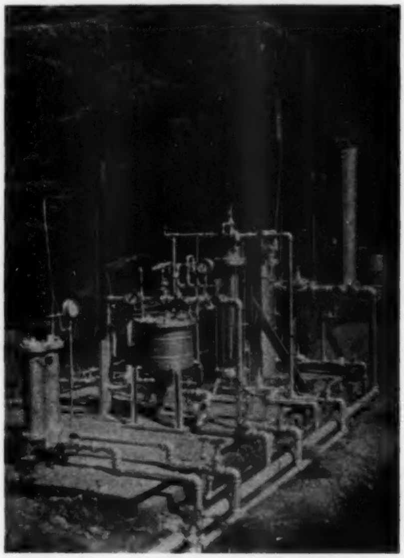

Fig. 2. Experimental Filter Plant

This general view shows the water deaerating tower in the background, and four diatomite filters.

to perform the four operations of the diatomite filter cycle automatically by means of hydraulic valves actuated by a central, single-knob control switch. This unit, in fact, served as a small scale model from which the operating needs of a large installation could be visualized (Fig. 2–3).

The work done with these commercial units yielded valuable information

on the best arrangement of inlet, outlet and backwash piping, valves and direction of flow; overall head losses of unit; the type of valves best suited for each function to be performed; design features which eliminate air-locks in the system; and the effect of dissolved and entrained gases in the water being treated.

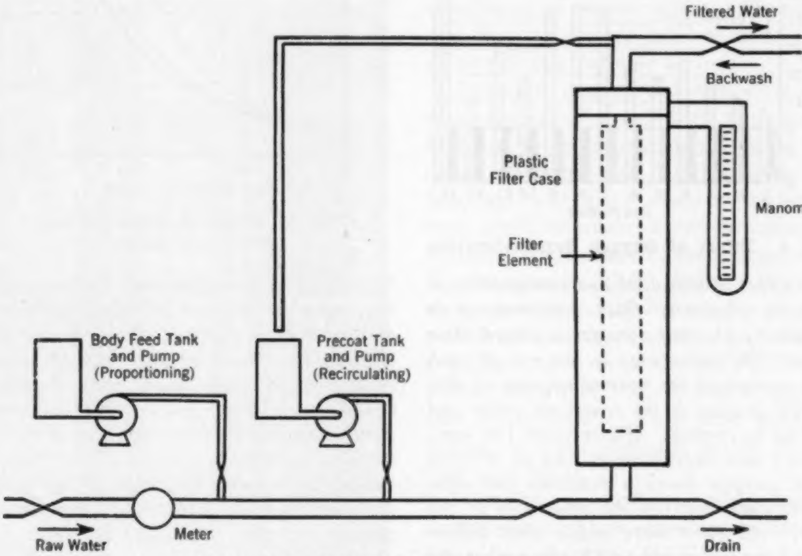

Fig. 3. Experimental Diatomite Filter Assembly

This schematic diagram shows the main elements of the experimental diatomite filter assembly.

The results of these experiments with different types of valves indicate that although quick-opening valves have been used to advantage for the backwash operation in small diatomite filters, their use in large-capacity plants is objectionable, mainly because of their tendency to produce water-hammer. The department's work indicates that slow-operating valves can be used in the water piping of the backwash system without impairing its efficiency, if a small quick-opening valve is used to operate the air vent on the filter. With the air vent valve, surging effects can be produced on the filter elements without endangering the water piping.

Improper construction of filter element caps and filter domes was found to be the cause of troublesome air locks in some of the available commercial diatomite filters. The difficulty was invariably overcome by improving design and providing air vents at the proper places.

Because dissolved and entrained gases in water are known to cause serious air-binding difficulties in the operation of rapid sand filters, a study was undertaken to determine the effect which the presence of gases in water would have upon the operating effi-

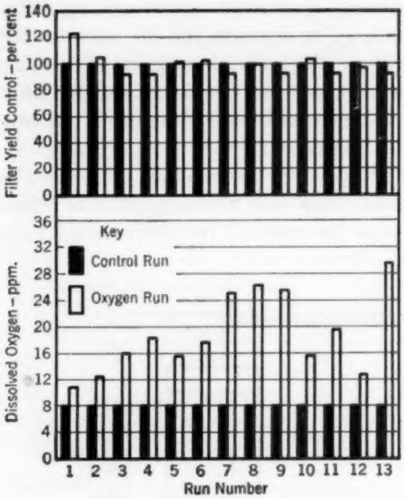

Fig. 4. Effect of Oxygen Supersaturation

The effect of dissolved and entrained oxygen on diatomite filter performance is shown by plotting data from paired filter runs. The water used in one run of each pair contained the normal amount of dissolved oxygen at the reservoir outlet and served as control. Water from the same service was supersaturated by an injector with oxygen from a pressure gas container and used for the other run of the pair. All runs were made with differential pressures up to 12 psi. across the filter membrane. The lower graph shows the difference in oxygen concentration in the water used for each pair of runs, while the upper graph shows the corresponding differences in yield of filtered water based on a 100 per cent yield for the control runs. The results indicate that dissolved or entrained oxygen in the water in concentrations from normal to almost four times normal has no significant effect on performance of diatomite filters operating under pressure.

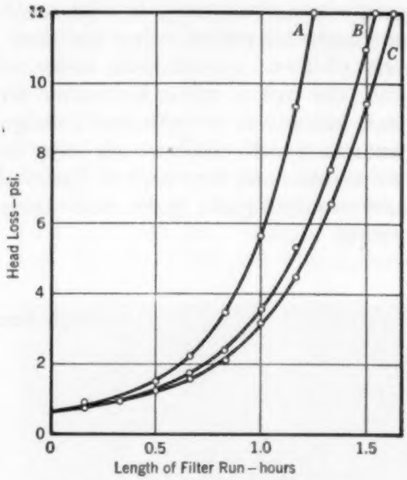

Fig. 5. Effect of Dissolved and Entrained Gases

The effect of back-pressure on the influence of dissolved and entrained gases on diatomite filter performance is shown by plotting the length of filter run for each increment of filter head loss. Similar conditions of water quality, filter-aid, and flow rate were used to show the effect of variable factors as noted. These graphs indicate a decrease in length of filter run for low pressure filtration of air supersaturated water, showing the effect of air-locking in the filter due to release of dissolved and entrained air. This is hardly noticeable in high-pressure runs.

Key to curves:
A—Air-supersaturated water low-pressure run (up to 5-psi. back pressure)
B—Air-supersaturated water high-pressure run
C—Deaerated water

ciency of diatomite filters. Air, oxygen and nitrogen were used to supersaturate water in different runs. The results were then compared with those of filter runs made with water containing the normal amount of dissolved gases and also with water which had been completely deaerated. A diatomite filter equipped with 14 filter elements having a total filter area of 11 sq.ft. was employed. The filtration rate used in these experiments was 2.8 gpm. per sq.ft.

As a typical example, the effect of dissolved and entrained oxygen on di-

atomite filter performance is shown by plotting data from pairs of filter runs as indicated in Fig. 4. The water used in one of the filter runs of each pair contained the normal amount of dissolved oxygen at the reservoir outlet and served as the control factor. The other filter run of the pair was made with water, obtained from the same service, which had subsequently been supersaturated, by means of a diffusing injector, with oxygen obtained from a pressure gas container. All the filter runs were made with differential pressures up to 12 psi. across the filter membrane.

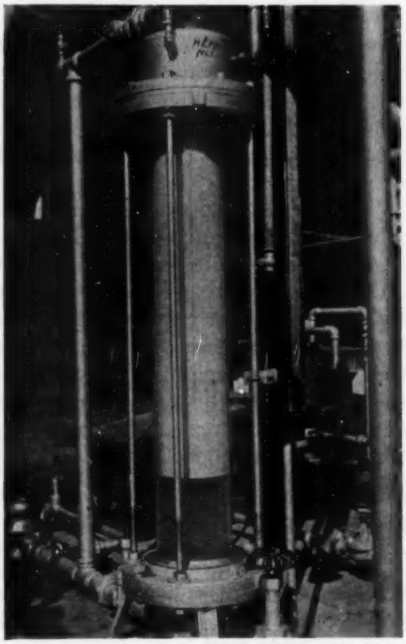

Fig. 6. Experimental Diatomite Filter

This view of the filter unit shows the precoat in place at the start of the run.

The results of this study indicate that the presence of dissolved or entrained gases in water treated in diatomite filters has no appreciable effect on the efficiency of the process, provided sufficient back pressure is maintained to prevent the release of gases in the filter. The effect of back pressure on diatomite filter performance when treating water supersaturated with air is shown in Fig. 5, in which the lengths of filter runs are plotted for each increment of filter head loss. Similar conditions of water quality, filter-aid, and flow rate were used to show the effects of the variable factors.

Although commercial diatomite filters proved to be useful for the overall study of filter performance, it soon became apparent that detailed study of filter-aid and filter element performance could be made more conveniently by using single filter elements mounted in transparent filter shells. In this way, observation of filter septa operation at all the stages of the process was feasible. As a result the HEFP No. 1 Filter, shown in Fig. 6, was designed and constructed. This unit enabled testing of filter elements up to 36 in. long and 4½ in. od.

In order to study possible length limitations of filter elements, a similar filter, known as the HEFP No. 3 was built. This model can be used for performance studies of filter elements up to 60 in. long and 5½ in. od.

Still another filter, a miniature type, designated HEFP No. 2, was designed and constructed for accelerated predeterminations of optimum filter-aid doses for any type of water to be treated, and for use as a portable experimental unit.

Filter-Aid Studies

The filter-aid process is generally predicated upon the premise that, to remove a particle of suspended matter of given size, the interstitial openings of the filter medium must be smaller

than the particle. Consequently, the degree of clarity designed in the filter effluent can be regulated by the choice of filter-aid (3).

The desired properties of a filter-aid are that it be a finely divided powder, highly porous, light in weight, insoluble, and without effect upon the chemical properties of the filtrate. Because diatomaceous silica (diatomite) has these essential properties, it has become the accepted material for the clarification of virtually all liquids which require filtration. Vast deposits of diatomaceous earth exist in many parts of the United States, notably along the Pacific Coast. Some of the largest and purest deposits of this material are located in California.

Diatomite filter-aids are available commercially in more than 10 different grades of porosity. These differences in pore size are microscopic but influence the rate of flow and degree of clarity of filter effluents greatly. Because of these varying filter-aid porosities, a grade of diatomite can be selected that will give the maximum rate of flow consistent with the desired clarification for a given process. After investigating the possibilities of seven grades of diatomite it was found that the four coarser products tested gave the longest runs with satisfactory effluent clarity, thereby being considered best for the treatment of water carrying an appreciable plankton load, such as that leaving open reservoirs in the Los Angeles water system.

In addition to the natural diatomite filter-aids, experiments have been conducted with an amorphous aluminum silicate powder containing 70 per cent silica and 30 per cent aluminum oxide. This is a synthetic product, lighter than diatomaceous earth, that tends to float in water. It appears to be more easily reclaimed than diatomite and requires smaller doses by weight for equivalent filtration results. Its present cost, however, places it at a disadvantage when competing with other types of filter-aid.

Several grades of commercial wood pulp products have also been tried as filter-aids. These products do not seem capable of producing filter effluents of a quality comparable to that obtained with diatomite. Certain grades will, however, increase filter runs without impairment of filter effluent quality when used sparingly in conjunction with diatomite, as either a body-feed or precoat.

These wood pulp products are more expensive than diatomite and their use as admixtures will prove economical only when they are used in the precoat for filter runs that require little or no body feed. This seems to indicate that the increase in length of filter run is the result of the formation of a ruffled surface that increases the area on which the suspended matter in the water can be collected.

Filter-Aid Requirements

The total filter-aid requirements include the amount of material used to precoat the elements as well as that used as "body feed."

In selecting the precoat material it is necessary to consider the porosity of the filter element septum used, the character of the suspended solids to be removed and the degree of clarity desired in the filter effluent during the initial stages of the filter run. The ideal amount of precoat material to use in any particular filter will be the minimum amount needed to protect the filter element from clogging while producing an effluent of the quality desired.

In the department's work, the optimum amount of precoat was determined by visual observation of filter element performance in the plastic-shell filter (Fig. 6) and by recording turbidities of the filter effluent at 10-minute intervals (Fig. 7). If water quality is not likely to fluctuate drastically, the optimum precoat for a given type of filter element, for all practical purposes, remains constant. Experimental results showed that for the types of filter septa used, operating at rates not in excess of 7 gpm. per sq.ft., the most economical precoat filter-aid doses, consistent with satisfactory initial effluent water quality, varied from ½ to ¾ oz. per sq.ft. of filter area.

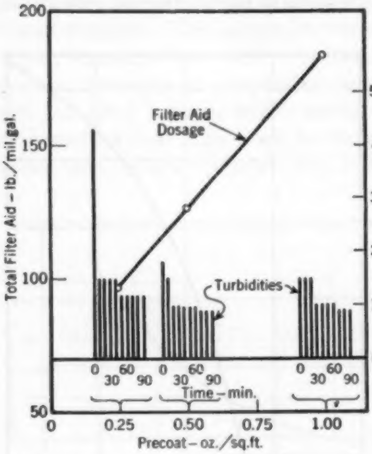

Fig. 7. Selection of Optimum Dose of Precoat

The vertical lines indicate treated water (filter effluent) turbidities as measured by the ordinate on the right side for successive time intervals for each of three precoat doses. The total filter-aid requirements are measured by the ordinate on the left side and are represented by points on the inclined line for the typical water treated. For these particular conditions, 0.5 oz. per square foot of filter area would be considered to be the optimum precoat dose. The filter rate was 6.5 gpm. per sq.ft.; the precoat was Celite No. 503 and the body feed was 9 ppm. of Celite No. 503.*

* *A product of Johns-Manville, New York.*

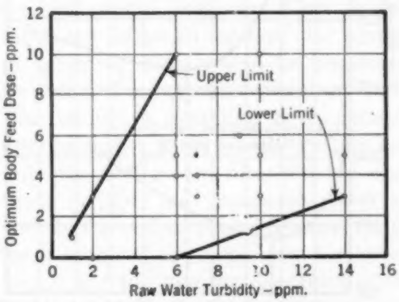

Fig. 8. Effect of Water Turbidity on Optimum Body-Feed Dose

The effect of raw water turbidity on the optimum body-feed dose is shown by plotting the turbidity and optimum body feed dose for a wide variation of raw water conditions. The upper and lower limit lines show the range that has been encountered with Hollywood Reservoir water within a year. Each of the plotted points represents the most economical body-feed dose determined experimentally (Fig. 9) for particular water quality conditions and type of filter-aid used in a given filter run.

Body-feed requirements are said to vary, in general, proportionately with the raw water turbidity, yet the evidence on hand indicates that body-feed requirements depend to a large extent upon the type as well as the amount of suspended matter carried by the water (Fig. 8, 9).

Inasmuch as it was noted that the optimum body-feed doses do not vary

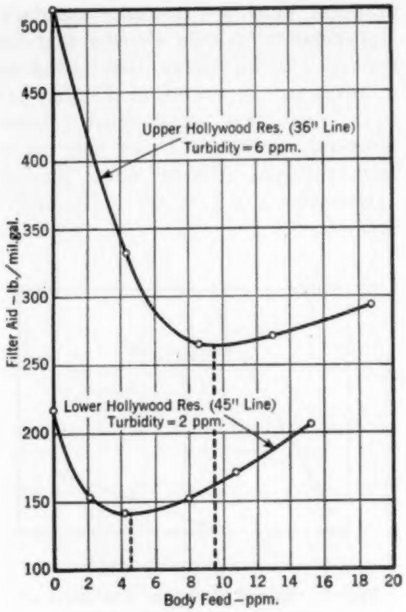

Fig. 9. Effect of Type and Amount of Suspended Matter on Total Filter-Aid Requirements and Optimum Body-Feed Dose

Two curves known as "optimum body-feed curves" (one for each of two different water sources) have been plotted from data obtained in a series of filter runs in which the only variable was the body-feed dose used. Optimum body-feed doses of 4.5 and 9.5 ppm. are shown in the graph for each of the two waters filtered. The type and concentration of organisms carried by each of the raw waters used are indicated in the plankton report below:

Organism	Average Size (Areal Standard Units)	Total Count (Areal Standard Units per ml.) Upper Hollywood	Lower Hollywood
Asterionella	1	88	133
Melosira punctata		36	—
Stephanodiscus	1	146	46
Stephanodiscus	4	42	—
Synedra pulchella		47	—
Navicula	0.5	—	3
Amphiprora	8	—	46
Coelastrum	1	—	35
Amorphus		400	—

appreciably, for all practical purposes, at different filtration rates up to 15 gpm. per sq. ft., it was possible to predetermine the most economical body-feed dose for any particular water by making three runs in a miniature filter at a relatively high filtration rate (from

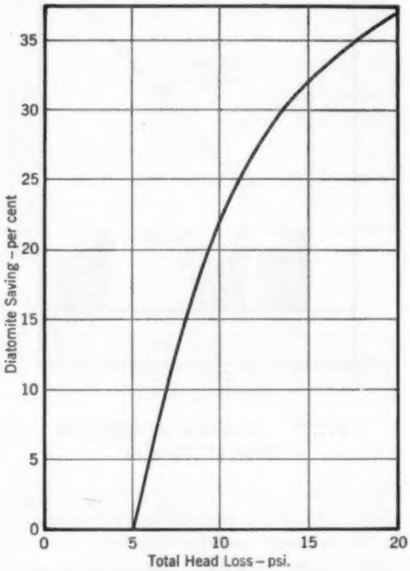

Fig. 10. Effect of Total Head Loss on Diatomite Requirements

The effect of increasing the maximum allowable filter run head loss on filter-aid requirements is shown by plotting the saving in filter-aid for filter runs made to a maximum head loss of 5, 10, 15, 20 psi. The saving is based on amount of diatomite used in the 5-psi. filter run.

10 to 15 gpm. per sq.ft.) using a different body-feed dose for each run and plotting total filter-aid requirements per million gallons of water treated against the body-feed dose used in each run (Fig. 9). Body-feed doses that varied from 1 to 10 ppm. were found suitable for the clarification of most of

the waters filtered at the experimental treatment plant.

At the length of filter run ordinarily attained with a maximum head loss of 10 psi., the total filter-aid requirements were found to vary from 50 to 250 lb. of diatomite per million gallons of water treated. The larger increments were required for water containing greater amounts of suspended matter and for filter runs in which powdered activated carbon was used to remove tastes and odors. Under the conditions prevailing at Los Angeles, and at the present market prices, the cost of diatomite has been estimated to be from one-third to three times higher than that of conventional water treatment chemicals.

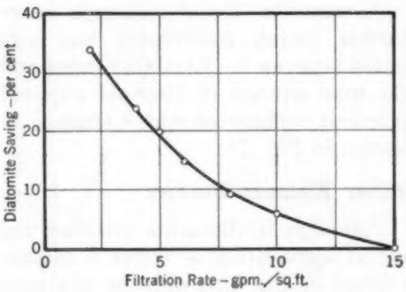

Fig. 11. Effect of Filtration Rate on Diatomite Requirements

The effect of filtration rate on filter-aid requirements is shown by plotting the saving in filter-aid at various filtration rates, over the amount of filter-aid required at an arbitrary maximum rate of 15 gpm. per sq.ft.

It was noted that, within limits, a reduction in filter-aid requirements per unit volume of water treated can be obtained by increasing the allowable pressure loss through the filters before discontinuing the filter run (Fig. 10). It was found that another way of reducing filter-aid requirements is to decrease filtration rates (Fig. 11).

A reduction in filtration rates, however, means an increase in filter area needed to filter a given volume of water. Faster filtration rates, on the other hand, mean lower yields (Fig. 12), shorter filter runs and more frequent backwashing.

An economic study in which the increased capital costs for filter equipment are balanced against the saving in operating costs would be necessary to select the optimum filtration rate. The saving in operating costs considered in such a study should include not only the savings on filter-aid but also those in labor and backwash water as well as the cost of the additional equipment required to compensate for lower yields and for standby operation while filters are being backwashed.

Filtrability Index

The "filtrability index," a term recently introduced by British water works literature, may prove to be an effective tool to predetermine optimum body feed requirements. This index was originally used to predict microstrainer performance.

Experimental observations with various filtering and straining media showed that the relation of rate of increase of hydraulic resistance to the volume filtered was proportional to the hydraulic resistance:

$$\frac{dH}{dV} = nH \quad \ldots\ldots\ldots (1)$$

Upon this basis, P. L. Boucher (4) derived an equation for the filtrability index:

$$I = \frac{l}{V} \log_e \left(\frac{H}{H_o}\right) \quad \ldots\ldots (2)$$

in which I represents the filtrability index, H_0 denotes initial resistance (head loss) of the filters and H the resistance (head loss) after the passage of a volume of water V. The values of H_0 and H must be measured at the same velocity and in the same units. The volume, V, is measured in cubic feet per square foot of filter area. The filtrability index can therefore be defined as a measure of the rate of increase of hydraulic resistance of a filter per cubic foot of water filtered through a square foot of filter area at a constant filtration rate.

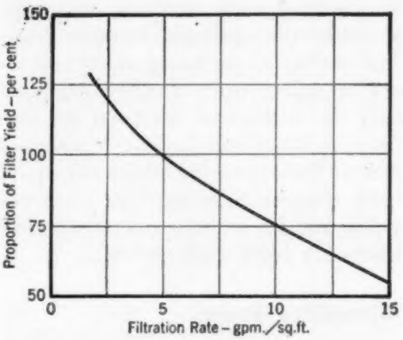

Fig. 12. Effect of Filtration Rate on Filter Yield

The effect of filtration rate on filter yield is shown by plotting the increase or decrease in filter yield for various filtration rates. The yield for the 5 gpm. per sq.ft. was arbitrarily set at 100 per cent. This is an average curve.

Since the department's experimental data indicated that for a given filtering medium the optimum body-feed dose is closely related to water quality, which in turn affects the rate of increase of hydraulic resistance of the filter, it seemed logical to assume that the filtrability index could be used as a short-cut for predicting optimum body-feed doses. To verify this hypothesis, a number of optimum body-feed values, obtained by the "sag-curve" method shown in Fig. 9, were plotted against the corresponding values of "I" computed by Eq. 2. The results, shown graphically in Fig. 13, indicate the close relationship between these two values. The rapidity and ease in which the value of "I" can be determined experimentally are decided advantages in favor of the filtrability index method of predicting body-feed requirements.

A somewhat looser, although nonetheless useful, relationship was also noted between the filtrability index and the total amount of filter-aid required per unit volume of water treated, as shown in Fig. 14.

Filter Element Studies

Although in diatomite filtration the actual clarification of water is accomplished by the filter-aid, the effectiveness of the process is in no small way dependent upon the type and design of the filter elements. These elements are the supporting members for the filter-aid, acting in this respect in much the same manner as the gravel layers and the underdrain system of a sand filter. Experiments have been performed using elements with septa made of: four types of porous stone; one type of plastic material; one type of Monel * wire; two types of stainless steel bands; five types of Monel, or stainless steel cloth or screen. A septum made with specially perforated plate, another of nylon filter cloth and a porous stainless steel septum have also been tried. These filter element septa have been rated on their ability to hold the various sizes of filter-aid, time

* A product of the International Nickel Co., New York.

required to precoat, initial head loss, rate of clogging, effectiveness of backwash and vulnerability to corrosion and deterioration.

The size of the openings in the filter elements under study varied from 25 to 250μ. In general, it was noted that the filter elements having the largest openings were found to require longer time to precoat. The difference in precoat time for openings up to 160μ, however, does not vary appreciably.

At recirculating rates of 2 gpm. per sq.ft., the filter element with the 250μ openings was precoated in from 6 to 10 minutes, whereas the 160μ size was always precoated in 3 minutes or less for the same precoat rate. The addition of small amounts of wood pulp products to the diatomite slurry has been found advantageous in precoating the 250μ material.

Conversely, the filter elements having the smallest openings precoat most quickly and easily but have a higher initial head loss, backwash less efficiently, are difficult to clean and tend to clog.

The shape and type of filter element opening and the design of filter element have been found to have a great effect on the initial head loss, rate of clogging and backwash efficiency (Fig. 15).

Most of the clogging in properly precoated filter elements seems to be caused by the finer particles in the pre-

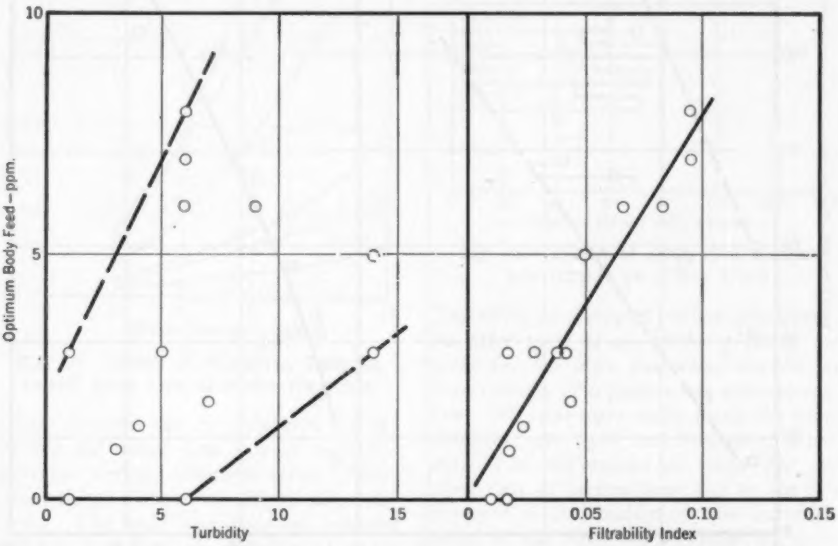

Fig. 13. Correlation of Turbidity and Filtrability Index With Optimum Body Feed

The lack of correlation between raw water turbidity and optimum body-feed dose is demonstrated by the graph on the left. The other graph shows the much closer relationship noted between the filtrability index and optimum body feed. Both were plotted from the same sets of filter run data obtained under a wide variety in water quality conditions for a year.

coat. The clogging is also more noticeable in element septa having considerable thickness and thereby presenting a more intricate path to the flow of water. Because of this failing, work was concentrated on the study of elements made up of thin metallic materials.

There is a limit to the size of opening that diatomite can bridge, but the largest opening capable of retaining the filter-aid should be used in order to minimize head losses and the effects of clogging. Smooth, clear openings on thin metallic plates were found superior to the wire cloth and screen metallic elements in these experiments.

Although the use of "double-wall" elements theoretically provides additional filter area for a given size of filter shell, their performance did not come up to expectations as a result of their tendency to clog in the lower portion. This clogging was due to inability to backwash properly because of the manner in which these elements are constructed.

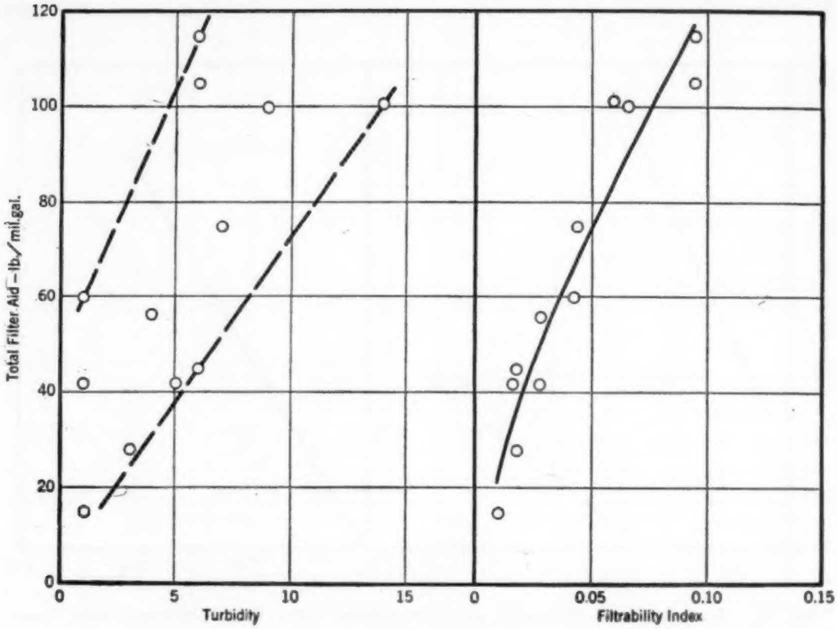

Fig. 14. Correlation of Turbidity and Filtrability Index With Total Filter-Aid Requirements

The usefulness of the filtrability index and raw water turbidity determinations are compared for the prediction of total filter-aid requirements. The filtering media and precoat dose remain constant.

The results of the experiments designed to obtain information on the maximum permissible length of filter

element indicate that, with the proper precoat dose, it is possible to use "single-wall" elements up to 48 in. long without much difficulty, and well designed elements even as long as 60 in. could be used. An important factor

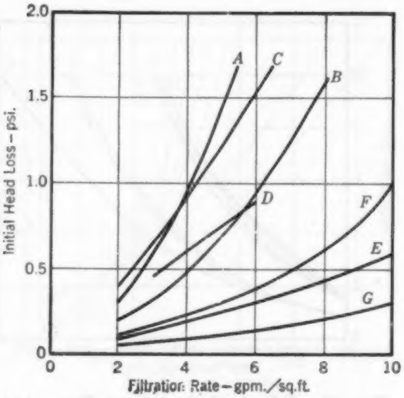

Fig. 15. Effect of Filtration Rate on Initial Head Loss of Filter Elements

Filter elements can be compared by observing the initial head loss of each element for various filtration rates. These relations are shown for several filter elements. The head loss indicated includes the total loss through the element and a precoat membrane consisting of 0.5 oz. of filter-aid per sq.ft. of filter area.

The key to the curves follows:

Type of Element	*Size of Openings* in.	μ
A—*48-in. double-wall Monel screen*	0.0064	160
B—*30-in. double-wall Monel screen*	0.0064	160
C—*60-in. stainless steel band*	0.0014	36
D—*Poro-stone medium*	0.001	25
E—*30-in. Monel screen*	0.0064	160
F—*36-in. perforated tube*	0.005	130
G—*30-in. square mesh screen*	0.01	250

for the successful precoating of long elements is to introduce the precoat powder in two or more stages.

Backwash Water Requirements

As with conventional filters, treated water should be used for backwashing

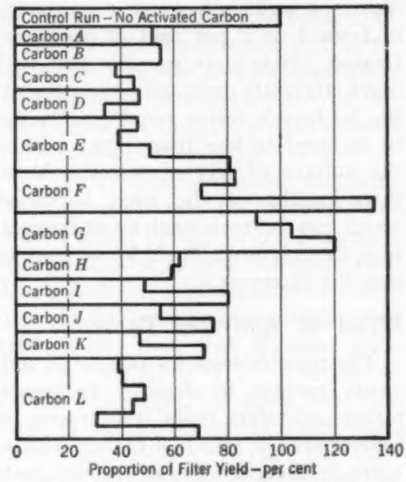

Fig. 16. Effect of Activated Carbon Admixtures on Filter Yield

The effect of activated carbon admixtures on filter yield is shown by plotting the yield for the filter run using carbon, as a percentage of a similar run without carbon. All runs were made using the same filtration rate, type and amount of filter-aid. The differences in yield for the same type of carbon were due to the differences in the quality of raw water filtered at the time the experiments were made. The precoat consisted of 0.5 oz. of Celite No. 545 per sq.ft.; the body feed was 3 ppm. Celite No. 545, the activated carbon dose was 3 ppm. and the filtration rate was 15 gpm. per sq.ft.

diatomite filters. The use of raw water for backwash is not only objectionable because it permits untreated water to enter the filtered water collecting system, but also because it contributes to the clogging of filter elements.

It was concluded that, for most of the elements studied, backwashing for 15 seconds at a rate of 20 gpm. per sq.ft. is sufficient for effective cleaning of the filters. On typical runs this in-

dicates a backwash water requirement of from 1 to 2 per cent of the water treated. It is quite possible that with more efficiently designed filter elements the backwash water requirements can be reduced to less than 1 per cent of the volume of treated water. About three-fourths of the used backwash water can be reclaimed by sedimentation, the clarified effluent being pumped into the reservoir.

Effect of Activated Carbon

The possible need for powdered activated carbon to remove occasional tastes and odors made it necessary to investigate the effect of carbon admixtures on the efficiency of the diatomite process (Fig. 16). The results of experiments with several types and grades of activated carbon indicate that diatomite is capable of retaining any of the materials used. The more finely divided carbons caused a decrease in filter yield, as was to be expected. Yet the coarser carbons used (over 90 per cent retained on a 100-mesh sieve) produced an actual increase in the yield. The activated carbon grades most commonly used in water treatment (over 90 per cent passing a 200-mesh sieve) caused a 50–60 per cent decrease in filter run yield. This loss of filter yield, however, can be avoided by increasing the body-feed dose from 1 to 3 times that required for filtering water without activated carbon treatment.

Inasmuch as the time required for water to cross the diatomite filter membrane is negligible, and contact is an important factor in activated carbon treatment, it is well to remember that for maximum efficiency an adequate contact period must be provided before the carbon reaches the filter elements.

Filter-Aid Reclamation

There are two problems common to both conventional and diatomite filtration processes. One is the need of transporting water treatment chemicals or filter-aid to the plant. The other

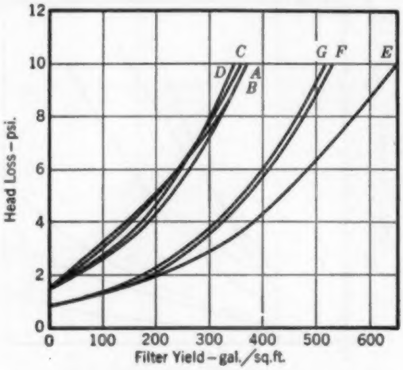

Fig. 17. Effect of Reclaimed Filter-Aid Particle Size on Yield

The effectiveness of reclaimed filter-aid material is shown by plotting filter yield against head loss curves for several filter runs made with various types of new and reclaimed filter-aid, using the same source of raw water and filtration rate.

The key to the curves follows:

Precoat: ¼ oz. per sq.ft. Celite No. 503
A—*3.0 ppm. Celite No. 503 (new)*
B—*3.0 ppm. Celite No. 503 (reclaimed with 2 percent chlorine solution)*
C—*3.0 ppm. Celite No. 503 (reclaimed wet without chemicals)*
D—*3.0 ppm. Celite No. 503 (reclaimed dry)*
Precoat: ¼ oz. per sq.ft. Celite No. 545.
E—*2.9 ppm. Celite No. 545 (new)*
F—*3.0 ppm. Celite No. 545 (reclaimed with 2 per cent chlorine solution)*
G—*3.1 ppm. Celite No. 545 (reclaimed wet without chemicals)*

is the need for disposing of the sludge produced in the treatment processes.

With an average total filter-aid requirement of 100 lb. per mil.gal., a 100-mgd. plant would require 5 tons of diatomite and would have to dispose of this material in addition to the load

of suspended matter taken from the raw water every 24 hours.

Although there is no indication at present that the supply of filter-grade diatomite is so limited as to justify partial reclamation of the used material, recovery of a considerable portion of the filter-aid may become necessary in order to minimize the load of suspended matter discharged into the sewers or storm drains.

In order to determine the best method of reclaiming the used diatomite and to test the effectiveness of the reused material as filter-aid, a number of experiments are being conducted using sedimentation and filtration as well as wet and dry oxidation procedures for the elimination or destruction of the organic matter present in the backwash sludge.

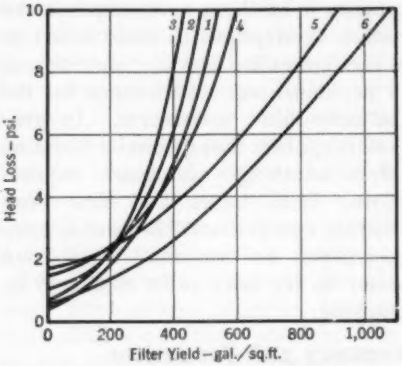

Fig. 18. Effect of Reclaimed Filter-Aid on Filter Yield

The relative effectiveness of reclaimed filter-aid material when used as precoat or body feed is indicated by the curves of filter yield plotted against head loss. All reclaimed material was saved from a previous run and treated with 2 per cent by weight of chlorine solution. The filter-aid was Celite No. 545.

The key to the curves follows:

No.	*Precoat* (¼ *oz. per sq. ft.*)	*Body Feed*
1	*New*	*None*
2	*Reclaimed*	*None*
3	*Third reclaiming*	*None*
4	*Reclaimed*	*Reclaimed (3 ppm.)*
5	*Reclaimed*	*New (3 ppm.)*
6	*New*	*New (3 ppm.)*

The data on hand indicate that with the finer filter-aid, the material reclaimed either by wet or dry processes does practically as well for body feed as new material, while with the coarser filter-aid the yield from reclaimed material is less than that obtained with new filter-aid (Fig. 17). The use of reclaimed filter-aid as body feed appears to reduce the yield more than when it is used as a precoat (Fig. 18). There is no evidence of water quality deterioration as a result of treatment with reclaimed diatomite.

A method sometimes advocated for reusing filter-aid involves the dropping of the used filter-aid by momentarily reversing the flow and replacing the sludge on the filter elements by the normal flow of water at the start of the filter run. Although this procedure has proved fairly effective when the practice is limited to one or two consecutive reuses, it has the disadvantage of allowing fine material to pass the filter during the first stages of filtration.

Removal of Microorganisms

The efficiency of diatomite filters for the removal of bacteria from swimming pool water has been reported to vary from zero to 96 per cent at various stages in the filter run (2). A similar trend has been noted for the coliform index. These results are in agreement with conclusions drawn at the experimental plant, where as a rule bacteria had been found in the filter effluent at the start of the filter runs.

The bacterial removal efficiency of diatomite filters, however, improves rapidly when the finer grades of filter aid are used, while the head loss through the filter membrane increases. For the most economical operating conditions, which involve the use of coarse filter-aids and thin precoats, there is a tendency for bacterial breakthrough, especially at head losses above 10 psi. It is obvious then that effective protection requires adequate chemical disinfection of the diatomite filter effluent.

The results of work done by Jones and Brady (5), using an experimental diatomite filter, indicate that these filters can be depended upon to remove the cercariae of *Schistosoma mansoni,* which cause dermatitis ("swimmer's itch"). This is a significant observation since cercariae are known to pass through sand filters and are resistant to chlorine.

TABLE 1

Comparative Advantages of Filtration Methods

	Conventional		Diatomite
Space requirements	10	to	1
Head loss (for maximum utilization of reservoir storage)	4	to	1
First cost	3	to	1
Chemicals or filter-aid			
Without activated carbon	3	to	4
With activated carbon	1	to	3
Personnel and maintenance	3	to	4

Diatomite and Conventional Filtration

Perhaps a better idea of the possibilities and limitations of the diatomite filtration process as it applies to the problems encountered in the Los Angeles system can be obtained from Table 1. This table shows the approximate ratio of space requirements, head loss and costs of construction, operation and maintenance for conventional gravity type rapid sand and diatomite filters.

In analyzing the information in the table, it must be kept in mind that because of the unprecedented filter capacities required in the Los Angeles projects it has been necessary to make certain assumptions in order to arrive at the figures for first cost and the cost of personnel and maintenance for the diatomite filter installation. In general, it appears that diatomite filtration offers advantages in space requirements, head losses and first cost, whereas conventional filtration is more economical in operation when head losses do not have to be recovered by pumping.

Summary and Conclusions

This study on diatomite filtration was undertaken for the purpose of determining the applicability and limitations of diatomite filters to the solution of water treatment problems at locations in the Los Angeles distribution system where lack of space will prevent the use of conventional facilities if additional treatment is deemed necessary at some future time.

In the preceding sections a summary has been presented of the work done to date on diatomite filter performance under wide variations in raw water quality; the applicability of commercially available mechanical devices for the operation of diatomite filter units; the performance of commercial filter-aids and filter elements; the determination of limiting head losses and of optimum filtration rates, filter-aid doses and backwash water requirements; the effect of dissolved and entrained gases on diatomite filter performance; the adaptability of diatomite

filtration to special processes for the removal of tastes and odors; filter-aid reclamation; effectiveness of bacterial removal; and the estimation of construction and operating costs of diatomite filter plants.

The work done indicates that for local conditions in Los Angeles the diatomite process is capable of producing filter effluents comparable in quality, from the physical standpoint, to those obtained with conventional procedures. This result is obtained without the use of chemicals and therefore does not change the chemical balance of dissolved substances in the water—a decided advantage in the treatment of the department's surface supply.

The experimental data so far obtained also indicate that for average water quality conditions the total cost per unit volume of water treated (exclusive of pumping) will be very nearly the same for diatomite and conventional filtration. If space is limited and pumping is necessary to regain head losses, the diatomite process has a decided advantage over conventional filtration. On the other hand, if the water carries relatively large loads of suspended matter and requires considerable treatment with activated carbon for taste and odor removal, if there is sufficient expendable head for the operation of a gravity rapid sand filter plant without recourse to pumping, and if sufficient land is available for the construction of the plant, conventional filtration appears to have the advantage.

It is hoped that further work on filter-aid reclamation may result in a more effective utilization of material and in a substantial saving in transportation requirements.

The filtrability index has been found to have potentialities for predetermining optimum filter-aid requirements.

Considerable work must be done to improve operating procedures in an effort to lengthen filter runs without sacrificing filter effluent quality. Lengthening filter runs will not only reduce filter-aid costs, it will also increase the effectiveness of the diatomite process for the treatment of water which contains taste- and odor-producing substances, and therefore requires powdered activated carbon treatment.

Acknowledgments

The authors wish to acknowledge the helpful cooperation of water treatment equipment manufacturers, of members of the Water Treatment Research and the laboratory staffs of the Division of Sanitary Engineering, Los Angeles Dept. of Water and Power. Samuel B. Morris is Chief Engineer and General Manager of the department and Burton S. Grant is Chief Engineer of Water Works and Deputy General Manager. Ray L. Derby, Principal Sanitary Engineer, under whom water treatment studies are conducted, is in charge of the Sanitary Engineering Division of the department.

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Discussion

By John E. Kiker Jr.

Professor of Public Health Engineering, University of Florida, Gainesville, Fla.

The foregoing paper is one of the most interesting the writer has read in many years. It contains a wealth of information, and from the viewpoint of a potential user of diatomite filters for public water supply, the paper is perhaps more complete than any of its forerunners on this subject. Indeed, in their summary and conclusions, the authors mentioned studies of at least eight different subjects on which comprehensive papers might profitably be written.

If the writer had any criticism of the paper at all, it would be for lack of details—yet it would have been manifestly impossible to cover any phase of the subject in sufficient detail within the allotted space or time. The paper leaves one with a whetted appetite for more of the actual operating data upon which the summary and conclusions are based. It is hoped that the authors will be given further opportunities to contribute to water works literature which is all too meager on diatomite filtration.

Individuality of Application

One of the most important principles brought out in the present paper, by implication, at least, is that each municipal supply for which diatomite filters are to be considered, should presently be regarded as an individual problem requiring special study.

In this connection it will be observed that the data in Table 1, on page 492, may apply only to the somewhat particular situation that prevails at Los Angeles. Head loss through a conventional rapid sand filter installation is represented, for example, to be four times the head loss through a diatomite filter, if maximum utilization is to be made of reservoir storage. Situations for which diatomite filters are so peculiarly adapted will be relatively rare, as it is well known that the actual head losses through diatomite filters are appreciably larger than the head losses through conventional rapid sand filters. It may be added parenthetically that we are fortunate in encountering such an uncommon situation as the one which exists in Los Angeles, because it is only through such circumstances that the water works profession will gather enough information to develop rational design criteria for diatomite filters within a reasonable time.

It seems that human nature is inclined to resist changes of almost any kind, and it is all to the good when we are forced into new developments which prove better than the old ones. This is not meant to imply that diatomite filters have "arrived" for the treatment of municipal drinking water supplies, or that they will become universally accepted for this purpose.

The writer believes that they have a particular value, as for example, in the treatment of water for swimming pools and for troops in the field—to say nothing of their use in industry—but he is not yet willing to sell orthodox pressure filters short if pumping would be required to regain head losses incidental to the use of gravity filters. The space requirements for the usual run of pressure filters, however, are obviously greater than for diatomite filters.

Filter-Aid Costs

A deterrent to the use of diatomite-type filters is the present high cost of filter-aid. In the example cited by the authors, filter-aid costs more than the chemicals which would be required at a conventional plant. The development of cheaper filter-aids, however, should result in more diatomite-type filter installations.

As mentioned by the authors, a relatively new filter-aid, amorphous aluminum silicate powder, has been placed on the market. This material has been used with much success at the University of Florida swimming pool filter installation. At present it costs more than diatomite, but the price should go down as production is increased, and its availability should be kept in mind if there is ever a shortage of diatomite.

The availability and use of various materials as filter-aids may preclude the use of the terms, diatomite filters and diatomaceous earth filters, in describing installations of the type under discussion. That, and for want of a better term, is the reason the writer would prefer to call them "diatomite-type" filters.

Just as the basic paper might have been developed to book length, so this discussion could be prolonged considerably. It must be ended, however, with much left unsaid—even without comment on the lengths of filter runs. But no such discussion should be terminated without making the observation that proper operation of diatomite filters requires a considerable amount of skill.

One may note also that the authors indicated that four people would be required for the operation and maintenance of diatomite filters for every three people employed at a conventional installation. A great deal of progress is nevertheless being made in diatomite filter developments, and the improvements may be accelerated in the future.

It has fairly recently been found unnecessary to disassemble the filters for cleaning when the elements become too clogged for effective cleaning by ordinary backwashing. Application to the filters of a commercial product consisting of a mixture of sodium acid sulfate, sodium bromide and potassium bromate has produced excellent results at the University of Florida installation. Others have reported the successful use of a buffered preparation of sodium acid sulfate without the addition of any bromine compounds. Other improvements will certainly be found as time goes on.

Filter Elements

The authors' comments on the types of filter elements are particularly interesting and it is almost inevitable that more information will soon be forthcoming on the relative merits of the different types of elements.

Some months ago the manufacturer of one type of element offered to replace the existing elements at the University of Florida swimming pool. Inasmuch as the existing elements have given satisfactory service it was decided to accept the new elements for one filter only, so that direct comparisons could be made between the two types. That was the last heard of the offer, although it is hoped that the comparisons may be made later.

Payment for Utility Changes in State Highways

By Harry B. Shaw

A paper presented on May 1, 1951, at the Annual Conference, Miami, by Harry B. Shaw, Deputy Chief Engr., Washington Suburban Sanitary Com., Hyattsville, Md.

THE cost of changing utilities in state highways, made necessary by the construction programs of the various state highway authorities, has become a matter of major concern to water works and other utilities. Often the subject of controversy in the past, this problem has assumed increasing importance as a result of the large volume and the nature of the highway construction that has taken place since World War II.

Extensive highway widening and resurfacing activities, improvement of the alignment and grade of highways to conform with modern traffic requirements, reconstruction of highways to withstand the heavy truck loads of today and the current, widespread superhighway and city bypass programs of the various state highway departments are the activities which frequently necessitate changes in water mains and appurtenant structures as well as in other utility works. The extent and nature of the changes involved add an additional burden to present high operational costs. In addition, many water utilities have for years past been operating at entirely inadequate rates, and they are or have been confronted with the necessity of increasing their charges. These factors combine to make the allocation of the cost of changing their utility structures in state highways a matter of serious moment to the water utilities.

Questionnaire Circulated

In order to find out what allocation was being made of the costs of changing utilities necessitated by highway projects, the following questionnaire was sent to the attorney general of every state and to the Public Roads Administration:

1. Does the state highway department or the utility pay for the relocation of or change in the utility's structures in state highways necessitated by the activities of the state highway department?
2. If the answer is to the effect that the utility pays for the changes, what is the general legal basis for it?
3. If the answer is to the effect that the state highway department pays for the changes, what is the general legal basis for it?
4. If, after consideration of existing conditions, it is generally felt by the people or the proper authorities that the procedure given in Answer 1 is unfair or inequitable, how can it legally be changed?
5. Does Answer 1 apply to both publicly owned and privately owned utilities?
6. If Answer 5 is negative, why?

7. Does Answer 1 apply to all types of utilities, such as water, sewer, gas, liquid fuel lines, electric power, communications, etc.?
8. If Answer 7 is negative, why?
9. What are the exceptions to Answer 1?
10. What is the legal basis for any exceptions?

Excellent Return

It is proper to acknowledge that the offices of the various attorneys general were most cooperative. Thirty-two sent in the information requested, or referred the inquiry to another state agency for reply, which was forthcoming without exception. Seven attorneys general personally transmitted the information, and several states advised that they were prohibited by law from furnishing such information.

The majority of the replies were accompanied by comments, often extensive, and sometimes even copies of relevant state laws or court opinions were furnished.

Occasionally the initial reply necessitated further correspondence, and the additional information requested was always furnished promptly and completely. The information about practice in the various states is thus factual, and sufficiently extensive to provide a good picture of the national situation.

Costs Borne by Utilities

The replies show that in the great majority of the states the utilities are required to bear the cost of changing structures, which were originally located within the state highway right-of-way, as a result of the state highway department's operations. The usual reason given for this arrangement is that the utility's right is subordinate to public use of the highway for travel. The reasoning is expressed by statute in some states, and in others by decisions of courts of law or attorneys general. The following statement by a former attorney general of Pennsylvania illustrates this concept well:

> . . . But further, not only does the State own the highways and have paramount authority as to their use, but, as *parens patriae,* her police power is supreme over the same. This power is based upon the maxim: *Salus populi suprema lex,* and extends, *inter alia,* to the promotion and protection of the public safety, convenience and general welfare of the people. All rights, franchises and property are held subject to its valid exercise. It cannot be contracted, bargained or charter-granted away by the State, nor has it ever been surrendered or transferred to the National Government. It is an inalienable and indefeasible power of the people of the Commonwealth. The present Constitution, in Section 3, Article XVI, declares:
>
> "The exercise of the police power of the state shall never be abridged or so construed as to permit corporations to conduct their business in such manner as to infringe the equal rights of individuals or the general well-being of the State."
>
> But this constitutional provision is largely declaratory. It expresses a basic governmental principle. . . .
>
> It results from what has been said that any franchise or privilege granted to lay gas pipes, water pipes or other structures in the surface or subsoil of any of the State's highways, was, at the time of the grant, is now, and at all times will be, subject to the State's exercise of her police power. This police power is a continuing power. Hence the grantees of such franchises have no vested rights or continuous easements in respect to the location or use of such structures, but such easements are subject always to the superior right of the State to require a change in the location, or in the mode

and manner of the enjoyment of the easement or privilege, at any time, as changed circumstances or conditions may make necessary or proper, in the interest of the public safety, convenience or general welfare. *Scranton Gas & Water Co.* v. *Scranton,* 214 Pa. 586 (1906). . . .

And these cases further establish that any resulting injury to the grantees' property, or expenses incurred, or loss or damage suffered, in consequence of this exercise of the reserved police power, is a *damnum absque injuria*; and is not a violation of either the Federal or State constitutional guarantee against deprivation of property without due process of law, nor a taking of private property for public use without just compensation.

And this ruling of the courts is equally applicable, whether the police power is exerted to promote the public health or safety, or the public convenience, or general welfare. (*Chicago, etc. R. R. Co.* v. *People of Ill.,* 200 U. S. 561 (1905); *Scranton Gas & Water Co.* v. *Scranton,* 214 Pa. 586 (1906)).

In the latter case the court held that: "The easement which a gas or water company has in the streets of a municipality, is subject to the superior right of the public both in the surface and the soil beneath the surface.

"Where a city changes the grade of a street in order to do away with a railroad grade crossing, and a gas and water company is obliged to move its pipes from the street by reason of the change of grade, the company can recover no damages from the city for the injuries sustained."

Exceptions

That some states take exceptions to the above legal philosophy was indicated by the replies received from California, Delaware, New Jersey and New York. In California the state pays utility relocation costs in freeways and in cities if the utility was installed before the state took over the street. In Delaware the expense of relocating or changing utilities as a result of the contruction or reconstruction of state highways through incorporated towns is borne by the highway department, if the utilities are municipally owned. It is principally in these towns, of course, that utilities have to be relocated.

In New Jersey the state highway department in general pays for the cost of utility changes when there is:

1. A grade separation or a highway vacation.
2. A radical change in grade necessitating a change in public utility structures.
3. A change requiring a longer overhead span for the public utility structures than is practicable (for the difference in cost between that of overhead and underground conduits).

In New York the expense of removal, relocation, replacement and reconstruction of water mains, sewer pipes and other facilities owned by any municipality and maintained for public use may be a proper charge against state highway funds. Also in New York the expense of relocating telephone and telegraph wires, power, transmission and gas, oil and water lines, conduits, cables of every kind in suitable facilities to be installed under, over and across any state throughway is deemed part of the cost of the throughway.

It is to be noted that California, New Jersey and New York apparently recognize that the development of highways to meet the needs of our modern civilization requires a somewhat different conception from that of "The King's Highway" or "El Camino Real."

The cost of the relocation of publicly owned water mains and sewers in both New York and Oklahoma is a state obligation when necessitated by highway changes, as it is with sewers in Kansas and sewers and certain other non-revenue producing utilities in California.

General Responsibilities

The great majority of the replies indicated that if the state highway department required the relocation of a utility structure which was in a private right-of-way previously acquired by the utility, the cost of such relocation was at the state's expense. This is the general result of constitutional provisions requiring that owners be duly compensated for property taken by the state.

Some of the replies simply stated that the cost of relocating utilities as a result of highway changes in their state was the obligation of the utility.

Time has not permitted complete examination of all cost responsibilities. Article V of the Bill of Rights, which states, "nor shall private property be taken for public use without just compensation . . ." would seem to preclude arbitrary governmental expropriation of utilities. It may therefore be suggested that the practice throughout the country is for the states to compensate utilities for changes necessitated by state highway projects in structures which were previously located in a privately acquired right-of-way.

Possibility of Revisions

In answer to the question asking how the present procedure of allocation of the cost of making utility changes could be revised, the majority of replies indicated that legislative action would be needed. Apparently constitutional changes would also be required in some states. Ten states simply replied, in effect, that no remedial action was required. It should, nevertheless, be noted that, at this writing, measures to amend the current procedure are being considered by the legislatures of at least four states and probably more. (In Maryland, such legislation recently passed the House of Delegates but died in the Finance Committee of the Senate.)

The replies indicate that the same procedure is generally followed throughout the country to pay for changing structures as a result of highway work, with both publicly and privately owned utilities. The previously mentioned practice with publicly owned systems in Delaware, New York and Oklahoma is an exception. In New Jersey there are many provisions in the law applying only to publicly owned utilities, and to the powers of municipalities over privately owned public utilities within their borders. In New Hampshire, railroads apparently have been the only type of utility affected by this problem.

Equal Application

The replies also showed that the payment procedure for utility changes is generally the same for all kinds of utilities, with the exception of those previously mentioned. It is of interest to note that telephone, telegraph, power poles and similar instrumentalities have a statutory right in the state highways in Oregon, whereas water mains, gas mains and similar facilities can be installed only by permission of the highway agency. (Just the opposite policy for the installation of structures exists

in Maryland in the Washington Suburban Sanitary District.)

Once the water or other lines are installed in the Oregon highways, however, the water utility seems to fare as well, or rather as badly, as the pole line utilities because both have to pay for the cost of changes to be made to their respective structures as a result of highway construction requirements.

Utilities Subordinate in Rights

From the replies to the questionnaire and the attendant correspondence it is quite plain that, over most of the United States, water and other utilities are legally regarded as having only a subordinate right in the state highways. The primary right in the highway is considered to be its use by the public for travel, and utilities cannot occupy the highways in such manner as to interfere with this purpose; to do so, it is held, "would infringe the equal rights of individuals or the general well-being of the State."

All of the above is apparently sound law, but its interpretation should be more realistic about the requirements of modern civilization. Law is often archaic in meeting the current needs of the people, and courts are traditionally bound by precedent. Life itself, however, is continuously changing. Laws which govern the lives of men should therefore be continuously reexamined for adequacy in meeting the needs of the people, and not be accepted without question simply because they can be traced to the edicts of the Medes and Persians.

When travel was established as the primary use of the highway, water mains, sewers, telephones, telegraph, fuel oil lines, power lines and underground cables of various kinds were almost or entirely unknown, and consequently unnecessary to the civilization then prevailing. All of them are necessary in modern living. The most logical method of providing the public with these facilities is by extending them in the public ways which provide individuals with access to their respective properties.

As the public, which has the paramount interest, is served by the utilities as well as by the highway, there is no logical reason for discriminating against the utility for merely being in the highway. Its existence in the highway is actually highly beneficial to the public—generally much more so than if it were in some other place. The highway is where the utility should usually be. It must always be kept in mind that the whole public interest must be served, not the wishes of an agency of the public.

Equities

The equities of the utilities and of the state which are involved in the payment for changes in utilities in state highways also deserve consideration. Only changes in water mains will be discussed, as they are the primary interest of water works men. As an example, it may be assumed that the state highway commission decides of its own volition that a certain roadway in which is located a water main (or other utilities) should be improved by widening and straightening and by improving the grade. Such a project involves considerable relocation and lowering of the mains and services of the water utility, and, therefore, considerable expense. Neither the water utility nor the public, however, has benefited from improved utility service. Maintenance costs, reflected in rates, have, in fact,

probably been increased. Why then should the utility or its customers pay for the cost of something from which they derive no benefit? The change was made at the direction of the highway agency so that it (the highway agency) could improve its service to the public.

If a water utility desires or is required to improve its service to the public by constructing a larger main, there is no question but that it should do so at its own expense. If in building the new main, other utilities or obstructions are encountered and extra expenses involved in crossing or changing them, this expense is considered part of the cost of constructing the new main and paid for by the water company. The owner of the interfering structure, if legally installed, should not be asked to pay for the change, as the water utility is asked by the highway people.

A public service is being improved and it is proper that the service which is being improved should bear the entire cost. Each agency can equitably charge the cost of the improvement to the persons benefited—the water utility in rates and the highway utility in taxes. The "highest use" of the highway has nothing to do with it. The public needs all uses of the highway. Failure to recognize this fact is unrealistic and is detrimental to the public interest.

What is the effect on public interest, which is the *sine qua non,* when a publicly owned water utility is required to pay for the cost of changing its structures as a result of a state highway project? The people served by the water utility pay, in their water bills or in local taxes, for the changes which the highway project forced the water department to make in its system. But that is not all. They must also pay their prorated shares as citizens of the state for the highway improvement itself. They are therefore doubly taxed. It is certainly not equitable to saddle a single community with the entire cost of a special part of a project of general benefit and then require that community to pay its proportionate share of the remainder of the project cost as well.

It appears to be evident that neither equity nor the public interest is served when a utility is required to change its legally located structures at its own expense as a result of changes required by a state highway project. The only justification is the doctrine that the state has a primary interest in the highway. But who is the state but its people? How then can a procedure which is not in the best interest of the people be justified? That, however, is what is happening, on the basis of *damnum absque injuria*—damage without injury. Law doesn't always make good sense.

Questionnaire

In order to determine what water works men think about this situation the following questionnaire was sent to a number of water works men throughout the country:

1. Who pays for changes to water utilities necessitated by the state highway department's operations? (Check items which apply.)
   a. The state highway department
   b. The utility
   c. Or both
2. Are you in agreement with the present system of payment?
3. If your answer to Question 2 is *No,* what changes would you suggest?

4. Does Answer 1 apply to all types of utilities, such as sewers, gas, liquid fuel lines, electric power, communications, etc.?
5. Whom would you suggest be questioned to ascertain the approximate annual cost of the changes in all utilities necessitated by state highway operations in your state? Please give name and address.

Replies

Of the 40 replies received, 13 favored the utility footing the bill for changes in its structures, 10 favored the sharing of the costs, and 17 thought that the state should pay it.

The comments of those objecting to putting the cost of utility changes on the utility indicated quite clearly that they had either given more thought to the inequities of the prevailing method of allocating the cost of utility changes as a result of highway operations or that they had been hurt more by it. The general tenor of the comments of those objecting to the prevailing practice was that the agency responsible for the project which necessitated the utility changes should pay for them, as they were part of the cost of the project.

Those who favored the principle that the utility should pay for the changes generally gave no reasons or held to the primary right principle. This reaction, however, is understandable. Persons objecting to a condition always have more to say on the subject that those who are satisfied with it.

The answers to the last question of the second questionnaire furnished little information. Of those replying, 24 suggested that state highway officials be asked for the desired information about the cost of utility changes in connection with state highway projects. Spot inquiries were accordingly made at the suggested sources, but the replies received pertained apparently to highway department expenditures only. Some thought the information would have to be assembled by the utilities themselves; others thought the information was not available; the rest did not answer the question.

Other Studies

While the inquiry indicated that the national cost of utility changes is not now available, the Maine Water Utilities Association sent out to the managers of water utilities in that state an inquiry on "Construction Costs Caused by State Highway Construction." The summary of the replies received by February 17, 1951, showed an expenditure by those answering of $105,871.96 for the years 1947–1950, inclusive.

Information was received that the city of Providence, R.I., spent more than $90,000 last year for changes in water appurtenances necessitated by highway improvements.

In an attempt to find out the extent of the problem in Maryland, the principal communities were asked what it cost them to change their water works structures as a result of operations of the State Roads Commission. Again the answers were not complete, but some interesting figures were given:

1. Hagerstown: One project, $57,-856.71.
2. Anne Arundel County Sanitary Commission: Recently, $5,500; with an additional $21,587 estimated at another locality.
3. Oakland: One project, $1,138.99. (In addition $6,000 was spent to carry water away from state road catch basins.)
4. Frederick: One project, $5,000.

5. Washington Suburban Sanitary District: $55,000 in the past three years. Two additional projects involving an estimated total expenditure for utility changes of $42,110 are now under construction. An extensive future highway program in the area will greatly increase the above amounts.

This information is of course very meager, and it is from only a limited section of the country. The aggregate cost for the country is probably astounding.

Summary

The situation that has been indicated by the current available data may be summarized by listing some outstanding facts:

1. Payment of the cost of changing utility structures on highway projects is exacted from the utility in the large majority of the states, on the grounds that the utility has an inferior right in the highway. There are, however, notable exceptions to this procedure.

2. It is apparently the practice, almost everywhere in the country, that if the utility acquired the right-of-way before the highway agency, the cost of changing the utility structures is the obligation of the state on the constitutional grounds that private property cannot be taken by the public without due compensation.

3. Legislation or constitutional revisions will generally be required to change the present practice of allocating the costs of changing utility structures on highway projects.

4. The practice generally is the same for all utilities, both publicly and privately owned.

5. There are numerous water works men, although not necessarily a majority, that take serious exception to the general practice followed in paying for utility changes in highways, and who feel that something should be done about it.

6. The exact cost to the water works industry of making these utility changes is not known, but it obviously is very substantial.

Suggested Practices

It is felt that certain recommendations might well be offered:

1. Each water works executive should give careful consideration to the problem, from the standpoint of both general considerations and the particular needs of his own utility.

2. Executives of all other types of utilities should act similarly.

3. The problem should be approached from the standpoint of what is right and equitable, keeping always in mind that the interest of the public is paramount. The idea of "The King's Highway," or travel as the highest use of the highway, should be dissociated from any odor of sanctity, even if it is stipulated by the state constitution. Constitutions were written so that they might be changed if it was in the interest of the public to do so.

4. If, after examination, the conclusion is reached that the present practice in a state for payment of the costs of changing utility structures in state highways is not equitable to the utility, facts and figures should be assembled to substantiate the reasoning and to show the magnitude of the problem to the community.

5. All available means to present the facts to the people who are served should be used—dodgers in utility bills, press articles, radio and television chats, talks before civic, service and business organizations. Organized groups should be encouraged to take positive

action in support of the position of the utilities.

6. This support should be organized in each community so that the endorsement of the local governmental authorities is obtained. If legislative action is required the representatives must be convinced of the soundness of endorsed policy and of the fact that the people wish it to be effected.

7. Utilities in each state should cooperate with one another to introduce legislation, properly drafted, to bring about the necessary changes in the laws or revisions of state constitutions. Water utility executives should fight for the passage of the legislation and see that their colleagues throughout the state do the same. They should make certain that the bill does not die in committee. A common way to kill legislation is to keep it from the floor of the body where it can be debated in democratic fashion. Debates may not convince legislators, but they do let the public know the position of the individual legislators on the matter.

8. It should be made certain that the governor is convinced of the merit of the legislation and signs it.

Action by A.W.W.A.

Actions which the A.W.W.A. could take to remedy this situation might include:

1. Organizing a special committee to make a comprehensive survey of the problem.

2. Instructing this committee to enlist the interest and cooperation of other utility associations.

3. Instructing the committee to work particularly on assembling factual data on the cost of utility changes in each state, so that this information can be passed on by the local utilities to the proper authorities for an understanding of the magnitude of the problem.

4. Instructing the public relations staff to prepare factual information on the subject in a form that will interest and can be readily disseminated to the public.

By working individually and collectively, this outmoded incubus upon utilities and the public which they serve can be overcome. The result will be greatly in the public interest.

Civil Defense in the Water Works Industry

By John S. Longwell

A paper presented on May 4, 1951, at the Annual Conference, Miami, by John S. Longwell, Cons. Engr., Piedmont, Calif.

CIVIL defense is a subject of paramount importance to all water utilities.

In any major catastrophe, such as may be caused by an enemy attack, water utilities must play a most important part.

In view of the present world situation, it is therefore timely to consider, seriously, the matter of civil defense in the water works industry.

The following phases of this subject will be presented:

1. A brief discussion of the overall civil defense picture.
2. A report covering progress to date on civil defense in the water works industry, as revealed by the answers to the questionnaire sent to all state sanitary engineers by A.W.W.A.
3. A review of civil defense efforts in California which involve the water works industry.

The Civil Defense Program

Everyone is undoubtedly familiar with the publication *United States Civil Defense* (1), released by the National Security Resources Board in the latter part of 1950. This publication presented "a plan for organizing the civil defense of the United States." It is a comprehensive statement, presenting a good basis for overall civil defense planning, and has been followed by most states in the development of their respective plans.

Federal Level

At the federal level, the plan provides for the establishment of a civil defense administration and the appointment of an administrator.

Since this plan was developed, Congress has enacted legislation establishing a federal Civil Defense Administration, and the President has appointed Millard Caldwell, former Governor of Florida, as the Administrator. Regional offices of this administration are now being established throughout the United States to further cooperation and coordination between the federal government and the states in each region. The Congress has not as yet enacted legislation to provide financial assistance to the states for carrying out the proposed program.

State Level

The plan sets forth a suggested model state civil defense organization which is to be headed by the governor through a director of civil defense. Administrative requirements are shown and discussed in considerable detail, and the need for the various divisions is fully set forth in the book. The suggested organization will of course not

be suited to all states, and must be modified as required to meet conditions as they exist in each state.

Recommendations are made that all states not having the necessary legislation to permit establishment of such a plan, take immediate steps to enact the required statutes.

Special attention is called to the need for having legislation adequate to cover mutual aid among cities, counties and other public agencies in the state, as well as between states.

Local Level

United States Civil Defense also sets forth in detail a suggested plan for local organization of civil defense to apply to cities, counties and other public agencies. Since the big responsibility falls upon the individual city or community in any disaster, the plan urges immediate action in line with the program adopted by each of the states.

The plan also recognizes that complete operating details must be developed by each state and by each city or community.

A.W.W.A. Survey

To determine what progress had been made in the various states and territories toward getting the water utility aspects of the civil defense program under way, the Association prepared and sent out a questionnaire to all state and territorial sanitary engineers in February 1951.

Replies were received from all 48 states and from the Territories of Alaska and Hawaii. A summary of the information submitted follows:

1. *Who is the state director of civil defense?*

The results show that 46 states and 2 territories have appointed directors of civil defense. In the two states that have not filled this position, enabling legislation is now being considered.

2. *Are you or some one of your staff officially a part of the civilian defense organization in your state?*

In answer, 39 reported *Yes;* 5 replied *No;* 1 said that the appointment had not yet been made; 5 indicated that legislation was pending.

3. *What is the assignment?*

The replies were:

In charge of environmental sanitation	29
State water coordinator	7
On advisory committees	3
Legislation pending	5
No assignment	6
TOTAL	50

4. *Is some water works executive an official member of the state civil defense organization?*

There were 20 *Yes* responses; 24 *No*; and the remaining 6 indicated that the personnel had not yet been announced, or that legislation was still pending.

These answers show that in only 20 of 50 states and territories have water works executives been appointed to the civil defense organizations. This seems to be highly inadequate representation for the water works industry.

Since water supply plays a major part in any civil defense program, the need for having water utility executives take an important part in the program should certainly be recognized. It would appear that water utilities have been somewhat negligent in getting proper representation, but perhaps it is still not too late to obtain additional appointments.

5. *Have you or your water works leaders set up a mutual aid program in your state?*

Of the 50 replying, 20 reported that such a program existed; 15 were with-

out it, and an additional 15 mentioned that the program was not complete or that legislation for it was pending.

The 15 states and territories in which nothing has yet been done toward establishing a mutual aid program represent 30 per cent of the total. Mutual aid is the basic part of any civil defense program and must be provided for if the program is to function properly, and if adequate aid is to be furnished to disaster areas. There has not, to date, been a full realization of the need for such a program. Whether or not there may be enemy bombing in any particular state, it may be necessary to furnish aid to communities in adjacent states. It is also essential that a program of mutual aid be developed to come into play in any extreme emergency—fire, flood, earthquake or other disaster. Such a plan should be in effect in all states, and soon.

6. *Is your state legislature considering any action which would authorize public officials to loan public property —or do they now have such authority?*

Such authority is now possessed by 18 states and territories; legislation granting the authority is now pending in 21; and there is no permissive legislation in 11.

Assuming that legislation will be enacted in all states where it is now pending, there will still remain 11 states not authorized to loan public property. Without such authority, mutual aid cannot function. It is therefore urged that further consideration be given by water utilities, in those states not having this authority, to the passage of adequate permissive legislation.

7. *Have you been informed concerning any orders or advice given by civilian defense officials that water works should employ special guards, build special fences, install protective lighting, etc.?*

Local officials had so advised utilities in 5 states; in the remaining 45, no orders had been received.

These replies would indicate that there has been no definite program set up at the federal or state levels advocating such protective measures. Sabotage is a matter of primary importance, and careful consideration in critical areas should definitely be given to security features. In line with this procedure, it will be advisable to maintain close contact with all law enforcement agencies and to make a comprehensive survey of all personnel in each utility.

8. *Have you heard of any civilian defense official advising high chlorine dosage as a counter-sabotage or protective measure?*

There were no affirmative replies.

Requirements of Water Utilities

In discussing civil defense planning, representatives of water utilities are primarily concerned with what steps are being taken toward developing a program that will enable the utilities to provide the best possible water service to the community in a bombing attack, earthquake, fire, flood or any other major disaster.

Unless the program will be of real assistance to the water utilities, it is not properly designed, and is not fulfilling the purpose for which it was intended. It is therefore essential that all water utilities take a major interest in the program now in the process of formation and activation in their communities and states, to see that the interests of the water utilities are properly provided for and that water works men handle water works problems.

California Civil Defense Plan

An outline of what has been done in California to develop a civil defense program appears below. It is not im-

plied that the California plan should be taken as a model. This outline is included merely to indicate some of the current thinking, and to show how the program is progressing. There are many details remaining to be ironed out before the plan will be fully workable and activated.

Disaster Act

The California Disaster Act of 1945, as amended in 1950, is the basis for the entire plan. This legislation provides for a state disaster council with such advisory committees and planning boards as may be appointed by the governor to develop the plan. The act gives the governor full authority to adopt the plan, and authority to declare an "extreme emergency" when, in his opinion, the best interest of the state or any portion of it, will be served by such a declaration. At such a time, the governor is in full command and has the authority to exercise all police power vested in the state by the constitution.

In conformity with this act, the state Disaster Council through its advisory committees and Planning Board has developed a state civil defense and disaster relief plan. This development has been proceeding since July 1950, when the advisory committees and Planning Board were appointed by the governor. The various parts of the plan have been released as they have been approved. The plan is being published in looseleaf form so that the parts or annexes, as they are designated, may be inserted in the book.

Utilities Plan

The annex that pertains particularly to the water works industry is No. 4c, entitled "Utilities." It covers all water, gas and electric utilities and sets forth the plan of procedure for utilities in the civil defense program. It is now being planned to transfer sewerage systems and sewage disposal from engineer services to utilities.

State Level

Annex 4c provides in general that there shall be, at the state level, a chief of the Utilities Division in the Office of Civil Defense who reports directly to the Director of Civil Defense or his deputy, and who coordinates the activities of the Utilities Division with the Divisions of Transportation, Supply, and Engineer Services. The chief of the Utilities Division will coordinate the activities of the water, gas and electric industries through an operating engineer, selected from each of these three utility industries, who will integrate each industry operation on a state-wide basis.

At present, the chief of the Utilities Division is Robert P. O'Brien, Supervising Engineer in the state Public Utilities Commission.

Utility Policy Committee and System Planning Subcommittees

The utilities annex has been drafted by the Utilities Advisory Committee assisted by a Utility Policy Committee, which is composed of the operating executives of representative public and private water, gas and electric utilities throughout the state, and by three system planning subcommittees for water, gas and electric utilities, consisting of representative operating administrators in each of these three classes of utility operation.

Chief of Utilities Division

In a state of extreme emergency, members of the Utility Policy Committee are on call to serve as chief of the Utilities Division, and it is anticipated that the person selected will be the

one whose utility system is least affected by the existing emergency conditions.

Operating Engineer

The state operating engineer for water utilities has not as yet been appointed, but the chairman of the water system planning subcommittee, Samuel B. Nelson, Assistant Chief Engineer of Water Works in the Los Angeles Department of Water and Power, through his subcommittee, is at present handling the duties of this position.

In extreme emergency, it is planned that all members of the water systems planning subcommittee will be on call to fill this position.

Channels of Communication

As plans are developed, the system planning subcommittees will set up the channels of communication between the state organization and individual water departments and water companies. They will also ascertain the persons in authority in the local utility organizations who will have been authorized by their organizations to receive instructions from the state Operating Engineer and carry out the directions of the state emergency organization.

Regional Level

The civil defense and disaster relief plan provides for dividing the state into ten regions as shown on a map accompanying the plan.

In the water works industry, where more than one water department or water company furnishes water in the region, operations will be coordinated by the regional representatives with the several water departments or water companies through a regional operating engineer. If it has not been considered necessary or advisable to appoint a regional operating engineer, however, the coordination will be obtained by the regional representative through the state operating engineer or directly with the representatives of the water departments or water companies involved. Consideration is now being given to the selection and appointment of operating engineers in the regions.

Mutual aid requirements and assistance will be coordinated by the regional or state operating engineer with the water utility operating staffs in the area or areas affected.

Local Level

It is planned that each water utility involved will have representatives on each county and city defense staff. These representatives will coordinate city and county requirements with local operating organizations of the utility or utilities serving the territory. Such arrangements have been made in many communities.

Requests for changes in water service arrangements and facilities, because of the emergency civil defense program, must be processed through the established commercial channels of the utility. During emergency periods, however, arrangements for such service will be coordinated through the civil defense organization functioning in the area.

Mutual Aid

All water utilities are required under the provisions of the California plan to maintain detailed records of:

1. Manpower available, including contract crews, by work classification and location.

2. Available materials equipment and supplies, by type and location.

3. Commercial sources of materials and supplies, together with the estimated potential inventory of such sources which may be available for use from time to time.

4. Amount of water which may be furnished from one water utility to another at all points of interconnection.

Such records shall, upon request, be furnished to the chief of the Utilities Division.

Available manpower, materials, equipment and supplies shall be dispatched to distressed areas as ordered by the chief of the Utilities Division.

Water shall be furnished from one utility to another at points of interconnection as ordered by the chief of the Utilities Division.

Established channels of communications to be used in emergency disaster operations are being coordinated by the civil defense organization, and the plan for use of such facilities by water utilities will be placed at each state and regional headquarters.

Medical and Health Services Division

The operation of water utilities in the California civil defense plan is under the jurisdiction of the Utilities Division, but the Medical and Health Services Division will, among its other duties, have supervision of health services as they pertain to water supply. It will be the duty of this division to see that the quality of water furnished by the utilities is satisfactory for maintaining the health of the community served.

The water departments and water companies, through their own staffs and laboratories, normally handle all matters of quality control under general State Department of Public Health supervision, but in periods of extreme emergency this arrangement may not be practicable. State laboratories may have to be utilized and closer state supervision of quality control may be necessary in the interest of the public health.

It may be necessary to put into operation wells that have not been used for some time, or to take water from other emergency sources. It may be necessary to furnish water by tank truck to hospitals, temporary medical stations or similar points of use. It will be the obligation of Medical and Health Services Division to supervise quality control as such situations arise.

Information will be developed and released by this division on biological and chemical warfare as it affects the water supply. Definite data on these subjects are somewhat limited at present.

Liaison Officer

The program will require close cooperation between the Medical and Health Services and the Utilities Divisions. To bring this cooperation about, the chief of the Medical and Health Services Division has appointed a full-time employee will supervise the sanitary features of the water utilities and operate through the staff of the Utilities Division. Good progress is now being made on this part of the program.

Radiological Services Division

The civil defense plan has recently been amended to establish radiological services as a separate division under the Director of Civil Defense. Previously it was a part of the Medical and Health Services Division as proposed in the organizational plan formulated

by the federal Civil Defense Administration.

The operation of this division is of great interest to the water works industry, as a ground or underwater burst of an atomic bomb, or an air burst during a rainstorm, might result in serious contamination of water supplies as well as injury to personnel.

Detailed information on radiological defense and detection will be made available to the water works industry, as well as to others, as the state program gets further along and its staff is activated.

From information currently furnished, the Radiological Services Division plans to provide monitoring personnel and equipment, and to take care of the radiological detection requirements for the water works industry, except possibly for a few of the larger departments or districts in the principal target areas. It is anticipated that these few water utilities will purchase and operate their own detection equipment. Some utilities have already purchased equipment of this kind and others are planning to do so. Monitoring equipment is available from several different firms.

Status of California Program

The program for water utilities in California is just getting organized and is still subject to change. In the next few months good progress should be made on inventory surveys and on the development of definite mutual aid plans. The other divisions, such as Radiological Service, Medical and Health Services, Fire Services, Engineer Services, and Supply Services, will, it is anticipated, be activated and coordinated with the water utilities.

It is hoped that the next year will see the program largely, if not completely, activated.

Participation by A.W.W.A.

In the development of the California plan there were two A.W.W.A. members on the Medical and Health Advisory Committee, one on the Fire Services Advisory Committee and two on the Utilities Advisory Committee. All of these men were appointed by the governor and were or had been connected with water utilities. In the Utilities Division, perhaps twelve other water utility executives, all members of the A.W.W.A., were appointed on special committees for the development of the utilities plan in the civil defense program.

Water Works Disaster Committee

The California Section of A.W.W.A., in August 1950, created a committee known as the Water Works Disaster Committee as a result of action taken by its Executive Committee.

The California Section of A.W.W.A. will assume the responsibility for the dissemination to its membership of disaster-program information pertinent to the water works industry, and will endeavor to get this information to the industry as a whole.

The committee has kept in close touch with progress made in the development of the state civil defense and disaster relief plan and the steps now being taken to place it in operation. Some of the committee members have also been members of the State Medical and Health Services, Fire Services and Utilities Advisory Committees. All of these committees have been advisory to the State Disaster Council.

Since its organization, the Water Works Disaster Committee has made three reports to the entire section membership on progress being made, and has assisted in furthering the activation of the civil defense plan. It has served as a liaison group between the civil defense organization and the water utilities.

Recommendations

It is to be emphasized that responsible federal authorities advise that the situation is serious, and that no time should be lost by water utilities in getting their houses in order. These authorities recommend that civil defense programs be activated in all states at the earliest possible date.

Water utility representatives should play a most important part in any such civil defense program, and in seeing that adequate provision is made for the proper handling of water utilities in times of disaster. It is recommended that water utilities adopt the policy that *water works men should handle water works problems.*

Reference

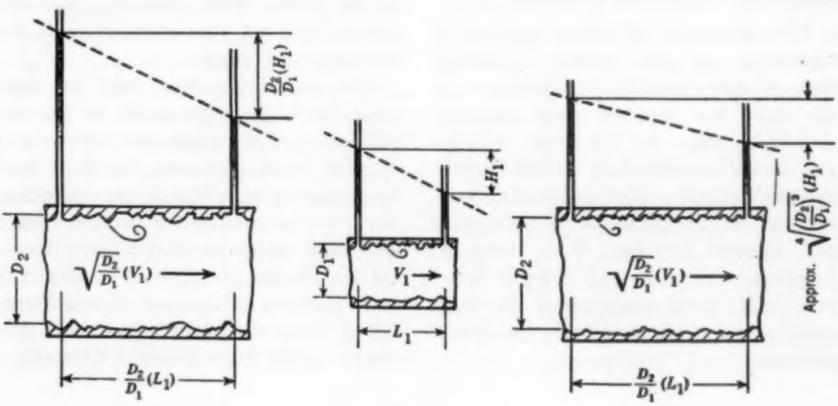
1. United States Civil Defense. National Security Resources Board Doc. 128. U.S. Government Printing Office, Washington, D.C. (1950).

Correction

Several typographical errors occurred in the paper "Relative Pipe Roughness" by Harry H. Chenoweth and Robert E. Leaver, as published in the March 1951 Journal. In Fig. 1 (p. 220), which is reproduced correctly below, the radical sign was omitted from the expression for the velocities in (*A*) and (*C*). In the figure caption, also, an error appeared in the second equation for f_2. The second term of the denominator of that equation should have been $\sqrt{\frac{D_2}{D_1}}\,(V_1)$ and not $\frac{D_2}{D_1}\,(V_1)$.

On p. 222, Eq. 5 incorrectly substituted f_1 for f in both terms preceding the equals sign. The equation should have read:

$$\frac{1}{2\sqrt{f}} - \log_{10}\sqrt{f} = \frac{1}{2\sqrt{f_1}} - \log_{10}\sqrt{f_1} + \log_{10} D$$



(*A*) (*B*) (*C*)

Studies in Local Production of Chlorine

A Panel Discussion

A panel discussion presented on May 1, 1951, at the Annual Conference, Miami.

Charles A. Black

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Although the process of generating chlorine by the electrolytic method was known in 1800, the first commercial production of electrolytic chlorine in the United States was in Rumford Falls, Me., in 1882. Several years later the production of chlorine at Niagara Falls in large quantities was undertaken because salt and economical electric power were abundant there.

It is interesting to note that the first expansion of the chlorine industry followed a typhoid epidemic in Niagara Falls in 1912. The largest production increase, however, came about when the pulp and paper mills began installing small plants to produce chlorine for use as a bleaching agent. By 1930 the paper mills were consuming about 47 per cent of the total chlorine supply, with 30 per cent being used for the manufacture of chemicals, 14 per cent for sanitation and 9 per cent in the production of textiles.

Government Controls

Between 1935 and 1940, electrolytic capacity was more than doubled. There was no apparent shortage of chlorine following this period until the outbreak of World War II, when the armament program took large amounts. In March 1941 the government added chlorine to the already expanding list of critical war materials. In June of that year the government ordered the pulp and paper industry to decrease chlorine use by at least 10 per cent. By July the Office of Production Management began control of the distribution of liquid chlorine.

During the war years the government used approximately one-third of the total output in order to satisfy the demand created by the manufacture of essential chemicals for wartime use. The government was unable to obtain the necessary amounts so its agencies constructed four new plants to contribute additional capacity. Between 1941 and 1944 the production of chlorine increased from approximately 800,000 to 1,260,000 tons per year. It is a well-known fact that during this period, even with increased production, there was a material shortage of the commodity.

Increased Postwar Needs

At the end of hostilities it was falsely predicted that there would be too much chlorine on the market, but instead of being cut back, chlorine consumption was actually increased. Until recently, approximately 6,200 tons of chlorine were produced daily in the United States, and it has been predicted that use in 1951 will exceed 10,000 tons per day.

Of the total amount of chlorine produced, less than 35 per cent is actually shipped for consumer use, with only 3½ per cent of the total used for sanitation purposes, including both water and sewage treatment. Logan (1) states that the water and sewage treatment demand for chlorine is not sufficient to influence materially the decision on the quantity and location of additional chlorine capacity.

It has also been noted that the purchase of containers for liquid chlorine has not accelerated as fast as production. And it is apparent that it is not profitable for manufacturers of chlorine to ship in less than carload lots into Florida because of the number of cylinder and ton container filling stations now in existence that are owned by private concerns. Although the cost for liquid chlorine has increased but slightly in single-unit tank carload lots, fob. works, there has been a great increase in delivered price for cylinder and ton container lots.

Purchasing Practices

The majority of water treatment plants in Florida utilize chlorine in cylinders, although until recently several of the larger towns purchased it in multi-unit cars. The present cost of chlorine delivered to points in Florida is given in Table 1.

Consumption Forecast

During the year 1950 the Orlando Utilities water plant used 69 tons of chlorine and the Orlando city sewage plant used approximately 72 tons—a total of 141 tons of chlorine, at a cost of $21,150.

It has been estimated by Robert and Co., consulting engineers for the Orlando Utilities Commission, that the annual water consumption at Orlando will reach 4,500 mil.gal. by 1955. Assuming proportionate chlorine consumption at the sewage treatment plant, approximately 205 tons of chlorine will be required annually by 1955 at a cost of $32,800, based on current prices.

Realizing the gravity of the present situation and responding to pressure from the water works industry, in January 1951 the National Production Authority issued NPA Order M-31. This order guaranteed chlorine to all public health users during 1951 in quantities equal to their 1950 consumption.

TABLE 1

Cost of Chlorine Delivered to Florida

	Price ¢ per lb.
Cylinders delivered	12.5–13.5¢
Ton containers	8.0– 9.5¢
Single unit cars (18 tons) delivered at Miami	4.3¢
Ton containers at Orlando	8.0¢

Because of the apparent chlorine shortage and increase in chlorine cost, the Orlando Utilities Commission directed an investigation to determine the feasibility of constructing a small chlorine plant to supplement its present water and power facilities.

Chlorine Manufacturing Methods

Chlorine is manufactured in the United States by four types of plant:

	per cent
Diaphragm cells	84
Mercury cells	7
Fused salt cells	8
Nitric acid process	1

The trend in commercial plants has been toward higher-amperage cells and consequently larger plants. The de-

posited diaphragm cell similar to the Hooker Type "S" has been used widely in larger chlorine plants in this country, although the trend in Canada and other countries has been toward mercury cells. Germany has been a leader in developing plants employing mercury cells for the production of chlorine and caustic soda. At the end of World War II a committee consisting of the leading authorities of the chlorine-alkali industry therefore inspected the German installations and returned with plant designs and operational data pertaining to these cells. As a result of that survey there has been an increase in the number of mercury cell installations, most of which have been large-scale operations.

Evaluation of Methods

An extensive investigation was conducted in order to evaluate the types and performance of the various cells now on the market which might apply to the construction of a small chlorine plant in Orlando. A number of the available cells were eliminated inasmuch as they were applicable only to large installations.

It was originally planned that the caustic and chlorine produced by diaphragm cells would be fed directly into the water treatment system without previous solution of the chlorine or concentration of the caustic. Although there would be salt leakage into the caustic, the chloride content of the treated water would be increased but 10 ppm.

The use of a mercury cell was then considered, thereby reducing salt consumption and feeding the gaseous chlorine plus 50 per cent caustic liquor produced, directly into the water treatment system. At this time the commission requested that studies be extended to determine the economics of providing sufficient chlorine for both the water and sewage treatment plants.

As the sewage treatment plant is located approximately eight miles from the water facilities, it was apparent that chlorine liquefaction would be necessary. With this added factor to consider, it was decided that a diaphragm

TABLE 2

*Comparison of Production Costs**

Raw Materials and Power	Unit Price	Diaphragm Cell		Mercury Cell	
		Unit Consumption	Unit Cost*	Unit Consumption	Unit Cost*
Rock salt, tons	$17.60	1.8	$31.70	1.8	$31.70
Graphite, lb.	0.24	6.5	1.56	7.0	1.68
Mercury, lb.	1.15	—	—	0.25	0.38
Power to cells, a-c., kwhr. (efficiency 80%)	0.0075	3140.0	23.55	4000	30.00
Steam, 1,000 lb.†	0.38	17.2	6.52	—	—
Total Cost			$63.33		$63.76

* Based on simultaneous production of 1 ton of chlorine and 1.12 tons of caustic.
† Steam cost based on low-pressure bleed steam.

TABLE 3

Allen-Moore Cell Maintenance Costs*

Material for Anode Repair (every 2½ years)	
24 graphite anodes	$50.09
1 concrete top	18.00
5 lb. putty	0.30
2 lb. asbestos wicking	0.49
TOTAL COST	$68.88
Materials for Cathode Repairs (every 1¼ years)	
20 lb. asbestos paper	$ 4.40
1 Cl_2 rubber tubing	0.13
H_2 rubber tubing	0.045
brine connector (rubber)	0.045
1–3 rubber gaskets for chlorine and hydrogen	1.13
1–2 stoppers on outlets	0.05
TOTAL COST	$ 5.80
Labor Costs for Complete Anode and Two Cathode Changes (every 2½ years)	
11 man-hours at $0.74 per hour	$ 8.14
Summary of Costs per Cell	
anode materials	$68.88
2 cathode materials	11.60
labor (cell repair)	8.14
daily maintenance ½ hour at $0.74 per 120 cells for 900 days	$ 2.80
TOTAL COST	$91.42

* Actual production of chlorine per cell over period of one complete change (900 days).

900 × 98.27 = 89,500 = 40 long tons

Cost per ton = 91.53/40 = $2.29 cell maintenance per long ton

= $2.03 cell maintenance per short ton

cell with salt recovery would be most satisfactory, as the chlorine plant with liquefaction facilities could be run continuously. The final decision to employ the diaphragm cell rested on the fact that a number of field investigations indicated that these were satisfactory for small installations. Cost data for construction, production and maintenance were also available. To the author's knowledge, no small scale mercury cell plant is in existence in this country, although the Monsanto Chemical Co. is constructing a small installation using the deNora type cell.

TABLE 4

Estimated Construction Cost

Chlorine plant equipment, including bulk salt handling facilities	$145,800
Chlorine containers for sewage plant	5,100
Building addition, including piping and wiring*	46,700
Engineering, legal and contingency costs	19,000
TOTAL COST	$216,600

* Building for chlorine facilities but not including storage space for water treatment chemicals.

Cost Analyses

Table 2 compares production cost for a typical diaphragm cell and a mercury cell. As no small mercury cells are known to be in operation, labor and maintenance costs could not be included. Table 3 indicates typical maintenance cell costs taken from actual operating data. Tables 4 and 5

TABLE 5

Cost of Producing Chlorine and Caustic

	Cost*
Salt, 1.8 tons at $17.60	$31.70
Power to cells, 2510 kwhr. d-c. or 3030 kwhr. a-c. at 0.75¢	22.80
Steam, 17,200 lb. at $0.38	6.52
Auxiliary power, 225 kwhr. at 0.75¢	1.69
Sulfuric acid, 16 lb. at $5.50 cwt.	1.00
Maintenance materials and labor	2.20
Labor for operation	18.00
TOTAL COST, excluding amortization and depreciation	$83.91
TOTAL COST, per pound	4.195¢

* Cost data given are for the simultaneous production of one ton of liquid chlorine and 1.12 tons of caustic soda.

indicate estimated construction and probable production costs, respectively, for the proposed chlorine plant at Orlando.

Proposed Orlando Plant

The site for the proposed chlorine plant is adjacent to the water treatment plant and uses the present chlorine unloading platform and railroad site. The housing would consist of an addition to the existing chemical house, with the same type construction. The plant will have a nominal capacity of 1 ton of chlorine and 1.12 tons of caustic soda per day; it will comprise:

1. Storage for bulk salt
2. Salt handling equipment
3. Brine purification
4. 24 Allen-Moore diaphragm cells
5. Motor-generator set—120-kw.
6. Chlorine coolers and dryers
7. Chlorine liquefaction equipment
8. Chlorine storage
9. Equipment for filling ton containers
10. Evaporator for reclaiming salt and purifying caustic
11. Hypochlorite production facilities

It was recommended that the commission employ a superintendent of chlorine plant operation in addition to the existing staff of skilled and operating personnel for the power and water plant that would be available for normal operation of the chlorine-producing facilities.

Conclusions

The results of this investigation indicate that a one-ton-per-day chlorine plant can be economically constructed in conjunction with the Orlando Utilities power and water plant using equipment of thoroughly proved performance. Reliable contractors and manufacturers are available who have constructed similar plants on which operational data are available over an extended period of time. The investment can be amortized over a period of from six to ten years, and at the same time make available to Orlando the critical products which are currently difficult to obtain. With the coagulation type treatment now employed at the water plant, water that is softer by 17 ppm. and of superior quality can be produced by replacing lime with caustic soda for stabilization.

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2. Chlorine. Chem. & Eng. News, **29**:364 (1951).
3. MacMullin, Robert B. Diaphragm vs. Amalgam Cells for Chlorine-Caustic Production. Chem. Industries (July 1947).
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6. Chlorination and Other Disinfection Practices. Chap. 9, *Water Quality and Treatment*. Am. Water Works Assn., New York (2nd ed., 1950).

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The ease with which chlorine may be produced by the electrolysis of brine, and with which its rate of generation can be controlled, may lead to the conclusion that after the installation of cells and a d-c. power source, all one has to do to control the sterilization of his water supply is to watch the ammeters and turn the rheostat

control to secure the optimum dose. This activity is actually about all that is required of the plant operator, but the care and maintenance of the cells is another matter and has led to the preparation of this discussion of local chlorine production.

Provision for Chlorine Generation

Provision for production of chlorine was included in the design of the Sacramento filtration plant in 1922 because of the prevailing high price of chlorine—approximately $0.13 per lb., in 150-lb. cylinders, larger cylinders having been unknown or unavailable at that time.

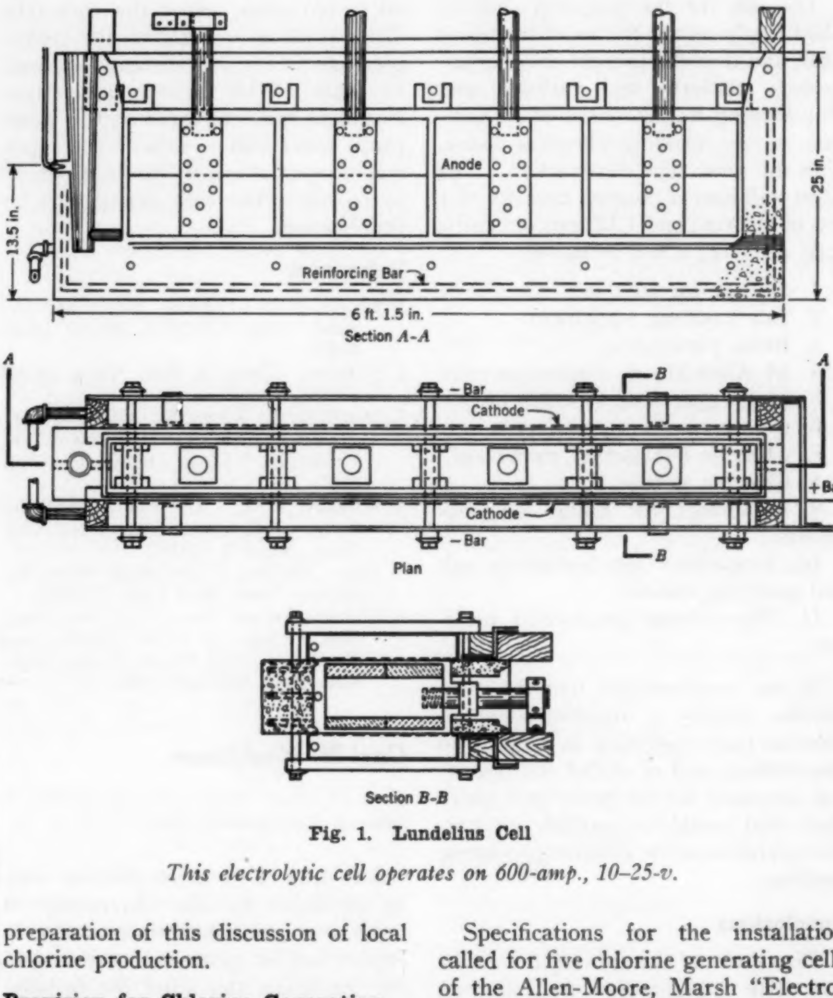


Fig. 1. Lundelius Cell

This electrolytic cell operates on 600-amp., 10–25-v.

Specifications for the installation called for five chlorine generating cells of the Allen-Moore, Marsh "Electro-Chlor," Nelson or Vorce type. Each of these cells was indicated to require a normal operating d-c. power of approximately 3.5 v., and at normal ca-

pacity of 300 amp. was expected to deliver approximately 19 lb. of chlorine in 24 hours.

Marsh cells were installed. Design provided for two clear redwood brine storage tanks (5 ft. in diameter and 5 ft. high), a brine pump, salt storage bins, brine saturator tanks, rubber chlorine pipe, and ejectors and hose for chlorine removal and application at the point of use.

For the necessary d-c. power, two motor-generator sets were employed, each consisting of a 300-amp., 9–18-v., separately excited d-c. generator, driven by a 10-hp., 3-phase, 60-cycle, 220-v. induction motor. Each generator was provided with two rheostats, one for the generator and the other for the exciter field control, thus providing generator voltage output which was accurately and easily controlled. Such control is necessary to maintain the full rated output of 300 amp. at any power from 9 to 18 v. for each generator.

Three industrial, metal grid resistors were provided to control generator output when varying numbers of chlorine generating cells were in the circuit. Each of the resistors had a 300-amp. capacity and a resistance equal to that of a chlorine cell (0.012 ohms).

All the chlorine-generating equipment was placed on three levels in the head house, but a marble control panel 24 in. wide by 84 in. high was mounted at an adjacent end of the filter gallery to facilitate control. On this panel were mounted three ruby and five white frosted flush lamps to indicate which of the three resistors and five chlorine cells were in operation. Generator and exciter rheostats and direct current ammeters and voltmeters, to indicate current feed and voltage, were included on the panel in addition to facilities for remote control of the generators and their driving motors. The filter operator was expected to be able, by proper operation from this panel, to control the chlorine output within the necessarily very narrow limits.

Early Operational Problems

The Sacramento filtration plant went into regular and continuous operation on February 12, 1924, using some old chlorinating devices from the original pumping station and cylinders of chlorine as standby equipment for some time.

The new chlorine production equipment was put into service shortly afterward and functioned smoothly for some time. It was soon apparent, however, that trouble would develop with the chlorine cells, largely because the space between anodes and cathodes was being clogged by caustic soda that was produced in the electrolytic process. This clogging caused inaccuracy in the expected chlorine output.

The check that was made of the chlorine residual in the filtered water revealed that chlorine output was not always directly proportional to the applied amperage. The cells deteriorated quite rapidly and required expert maintenance work by the plant machinist and electrician. It was obvious that something had to be done to maintain chlorine production on the required scale.

The solution was found by Charles Lundelius, who was then in charge of the coagulant manufacturing plant, but who had formerly worked for an industrial plant near Niagara Falls. He was given permission to design a cell that he felt would function more satisfactorily. The cells he designed were built at the plant—with the exception of the carbon anodes, which were purchased in stock shapes, and the per-

forated steel plates, which were readily available. The cast-iron cathode pans were cast in a local foundry.

The Lundelius Cell

The six new "Lundelius" cells each consisted of the following essential parts:

1. A U-shaped concrete block body approximately 5 ft. long by 3 ft. high, with necessary cored holes and embedded studs. (It was found desirable to make a regular form for these castings which could be stored and reused.)

2. A set of four carbon anodes, each made of a 2-in. round carbon rod screwed into a rectangular 4-in. carbon block, to which were attached four carbon plates of $6 \times 12 \times 1$-in. size. This construction provided an exposed exterior carbon anode surface of 8 sq.ft. for each cell. The carbon plates were attached to the 4-in. square carbon blocks with five accurately tapered dowel pins, each approximately 5 in. long.

3. Two cathodes, one on each side of the cell, consisting of a special cast-iron flanged pan, to which was attached, by flush, flat-head machine screws, a multi-perforated steel plate with perforations approximately $\frac{1}{8} \times 2$-in. Over this was applied a sheet of asbestos paper approximately $\frac{1}{16}$-in. thick to slow down passage of brine through the cell. Saturated brine was fed automatically to each cell from a float-controlled feed box, in order to flow around the anodes, and, as low-voltage direct current was applied, the electrolysis of the saturated brine produced chlorine, hydrogen and sodium hydroxide.

Operation of the New Cells

The new cells were installed outdoors, and since they were designed for 600- instead of 300-amp. operation, a new 600-amp., 10–25-v., separately excited, d-c. generator was purchased at a cost of about $1,750. Connections were made for parallel operation of the two 300-amp. generators. These cells were operated continuously for more than four years.

Chlorine was removed from the cells by hard rubber ejectors through lead and rubber conveyors. Hydrogen that was generated was allowed to escape into the atmosphere and the sodium hydroxide produced was drained off to a nearby filter.

It is believed, although without proof, that the extreme variation in rated output to which the cells were subjected may have been one of the factors causing the operating difficulties. It was found that the accumulation of white caustic soda between the carbon anodes and steel and iron cathodes caused partial short circuiting of the cells, thereby making it impossible to rely upon their rated capacity.

The high current rating of the cell, although spread over 8 sq.ft., caused a rather rapid breakdown of the tapered carbon pins by which the anode carbon plates were mounted on the 4-in. square carbon anode blocks. The 2-in. round anode carbon feed rods were also broken down until a method of shielding them with short glass tubes was developed. It is believed that a redesign of the carbon anodes might overcome these troubles, but the dissociation of the carbon is at best rather rapid.

It was found that the perforated steel screens needed rather frequent replacement, but the cast-iron pans, concrete bodies and asbestos-cement cell covers gave long and very satisfactory life.

Observation showed that it was best to open up a cell after about 30 days of operation, clean out any caustic and

make any necessary repairs to carbon anodes, asbestos filters and steel cathode plates. This work requires the services of a skilled plant machinist and electrician plus some common labor.

Costs

The production of chlorine at the Sacramento plant was carried on continuously from February 1924 to May 1930. The average cost of a-c. power during this period was 0.882¢ per kwhr. Although records on the subject are not readily available at present, the current consensus is that the chlorine produced cost between 6¢ and 7¢ per lb. In 1930 it became possible to purchase chlorine in 1-ton containers at 3¢ per lb. and haul it almost 60 miles to the plant.

As it was impossible to compete with this figure, and, as the maintenance men were needed for other work, the manufacture of chlorine was abandoned. The direct current generators and cell forms are still at the site, however, and operation could be resumed if desired. The present cost of purchased chlorine at plant is about 5.4¢ per lb.

Conclusions

Local production of chlorine and its control is relatively simple and requires inexpensive raw materials. The plant requires special equipment which, though built for particular use, is available in the general market from established manufacturers. Special cells may be designed to meet specific needs and built locally. Plant maintenance requires permanently available skilled and experienced mechanical and electrical help in addition to common labor, since maintenance may be required at any time. Emergencies, however, may be minimized by frequent inspection and repair.

Individual circumstances, economically evaluated, must be the basis for determining whether purchased or locally produced chlorine is to be used. If purchased chlorine is unavailable or prohibitive in cost, careful consideration should be given to local production.

The cost of locally produced chlorine at the Sacramento plant would probably be somewhat higher at present than the 6¢–7¢ per lb. cited, as material and labor costs have increased. Electric power costs in 1950 (0.78¢ per kwhr.) are lower than they were twenty years ago.

The preceding discussion has presented a more contemporary picture that is recommended for careful study. Many of the difficulties experienced twenty years ago would quite likely be overcome by modern cell design, supplemented by careful routine maintenance.

Ion Exchange for Water Treatment

By E. B. Showell

A paper presented on November 3, 1950, at the Chesapeake Section Meeting, Wilmington, Del., by E. B. Showell, Water and Trade Waste Consultant, E. I. du Pont de Nemours and Co., Wilmington, Del.

ION exchange—the exchange or replacement of one ion with another—is not one of man's inventions. It exists and has long been observed in nature, enabling vegetation to grow and softening water which percolates through such natural ion exchangers as the thick beds of glauconite-rich greensand found in the soil of the Coastal Plain Province from Long Island to Texas.

The first use of ion exchange for water treatment utilized this greensand—known commercially as "zeolite"—to soften water by base exchange, replacing calcium and magnesium, which are weak bases, with sodium, a strong base. Since then various modifications of the method have been adopted for the softening of waters, particularly by industries, which have found the process of great value to their operations.

This discussion is limited to the application of ion exchange to water treatment and does not consider its use in the chemical industry. Such water treatment processes as hot and cold lime-soda softening, softening with phosphates and softening with barium salts, which also reduce the amount of dissolved substances found in water, are only briefly referred to for comparative purposes.

The average industrial raw water is approximately 99.98 per cent "pure"; the remaining 0.02 per cent (equivalent to 200 ppm.) consists of ions dissolved in the water. If not removed, these ions may interfere with the use of the water in industrial processes or for boiler feed.

Sodium chloride does not produce hardness in water and can be deposited in a boiler in high concentrations with no harmful effect. Calcium carbonate and calcium sulfate do cause hardness and, if permitted to remain in the water, form scales in boilers and curds with soap. They will also degrade certain chemical products and interfere with dyeing. If the calcium ions can be replaced with sodium ions to form sodium carbonate and sodium sulfate, the troublesome scale-producing ions will be removed, and soft water results. Such a replacement of the ions of calcium and magnesium with those of sodium was accomplished in the first application of ion exchange.

Ion-Exchange Units

An ion-exchange unit consisting of a tank closed at both ends is shown in Fig. 1. The diffuser or collecting and distributing device, located in the bottom of the tank, may be a plate, as shown, or a strainer system with header lateral pipes, which include strainers of various types or orifices.

The gravel is graduated in size from coarse (1 in. to $\frac{3}{4}$ in.) down to the $\frac{3}{8}$- to $\frac{1}{4}$-in. range or smaller. Ion exchange materials are placed on the

gravel in depths which are varied to give a desired capacity and in sizes which depend upon the character of the water. The distributor is located several inches above the top of the exchanger and consists of perforated pipes, in spider form, through which flows downward through the exchanger, out the bottom, up through the multiport valve on the outside and through the meter to the service. This procedure continues without interruption until the ability of the exchanger to replace ions has been exhausted.

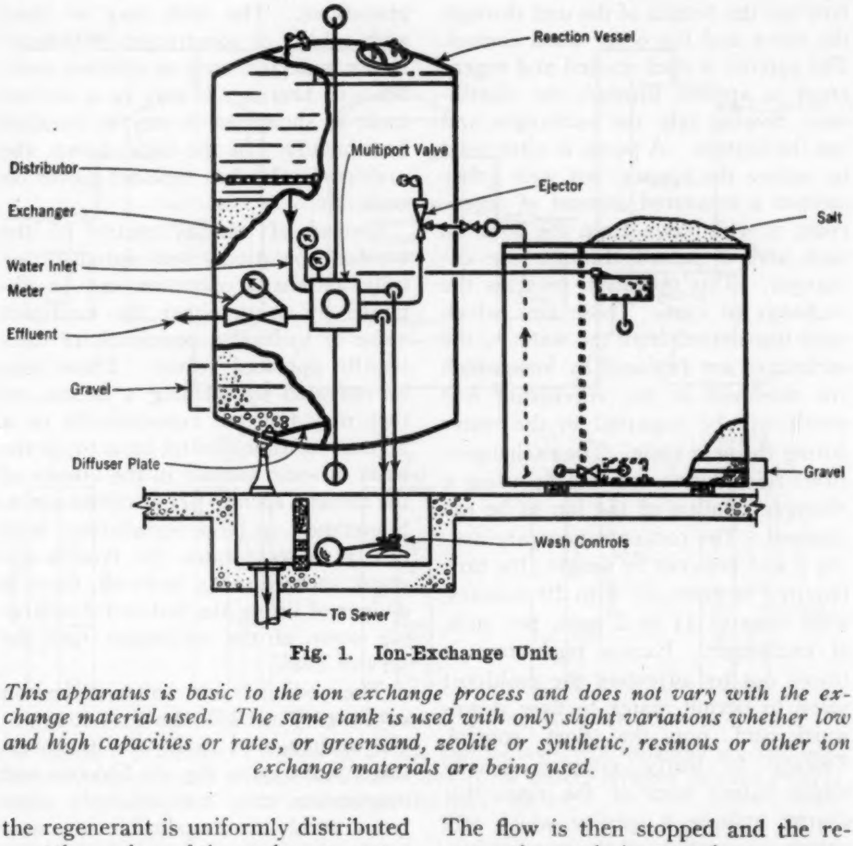


Fig. 1. Ion-Exchange Unit

This apparatus is basic to the ion exchange process and does not vary with the exchange material used. The same tank is used with only slight variations whether low and high capacities or rates, or greensand, zeolite or synthetic, resinous or other ion exchange materials are being used.

the regenerant is uniformly distributed over the surface of the exchanger materials. Although the distributor is sometimes used to collect backwash water, it normally serves only to distribute the regenerating solution.

Raw water enters the exchange unit through a multiport valve and is conducted to the top of the tank. It then The flow is then stopped and the regeneration cycle is started.

To backwash the unit, the multiport valve is adjusted to permit a reversal of flow. The water flows upward at a velocity sufficient to expand the bed of exchanger material, thus loosening the grains which may have become packed and washing out any suspended matter

that may have been deposited in it by the inflowing water. The wash water then flows out the top through the multiport valve to the wash control and the sewer. This operation usually continues for about ten minutes.

For regeneration, the multiport valve is adjusted to permit water to flow out the bottom of the unit through the valve and the other wash control. The ejector is then started and regenerant is applied through the distributor, flowing into the exchanger and out the bottom. A pump is often used to replace the ejector, but with either method a measured amount of regenerant is withdrawn from the solution tank and is passed through the exchanger. This operation reverses the exchange of ions. Those ions which were transferred from the water to the exchanger are replaced by ions which are dissolved in the regenerant and which will be imparted to the water during the next cycle. The exchangers effect this reverse reaction by using a stronger solution of the ion to be exchanged. The concentrations are usually 2 to 5 per cent by weight; the time required is generally 8 to 10 minutes, with rates of 1½ to 2 gpm. per cu.ft. of exchanger. Excess regenerant is rinsed out by adjusting the multiport valve to permit water to flow downward and out the float control. Twenty to thirty minutes usually elapse before tests of the rinse discharge indicate a quality which will permit resumption of the normal ion-exchange cycle.

The ion exchange material used does not alter the basic construction of the exchange shown in Fig. 1. The same tank is used, with only slight alterations, for both low and high capacities and rates, whether greensand or zeolite, or synthetic, resinous or other ion exchange materials are used.

Variations

A number of variations are possible in the collection and distribution arrangements of the unit. Anthracite coal may replace gravel in acid-cycle operations. The tank may be lined with rubber or constructed of noncorrosive materials, such as stainless steel, brass or bronze. It may be a vertical tank, as shown, or it may be installed horizontally. In the tank shown, the multiport valve has replaced valves on each line.

Instead of manual control of the various operations, semi-automatic or fully automatic operation can be obtained by using either the multiport valve or hydraulic, pneumatic or electrically operated valves. These may be operated by pushing a button, or they may function automatically on a volume- or time-control basis or on the basis of some variant in the quality of the effluent, such as pH or conductance. Sometimes, in large installations with nearly constant rates, the flow is upward; in such cases, however, there is danger of lifting the bed and discharging some of the exchanger into the service lines.

The sodium cycle softener (cation exchanger) used in the first commercial exchange of basic ions to soften water is shown in Fig. 2. Calcium and magnesium ions, comparatively weak bases which are responsible for most hardness in water, are exchanged for sodium ions, a strong base which does not cause hardness. The basic tank design shown in Fig. 1 has been simplified for clarity and the unit is assumed to be filled with zeolite. If a hard water, similar in composition to that shown in Fig. 2, containing cations and

anions in solution—the cations including sodium (Na), calcium (Ca) and magnesium (Mg); the anions including bicarbonate (HCO_3), chloride (Cl) and sulfate (SO_4)—is passed through the cation exchanger tank as illustrated, the result will be the sodium-cycle softened block. The dium base replaces the weaker calcium and magnesium bases. This is known as the sodium cycle and may be repeated almost indefinitely, year after year.

With the continued use of ion exchange, the greensand first used as an exchanger was supplemented by arti-

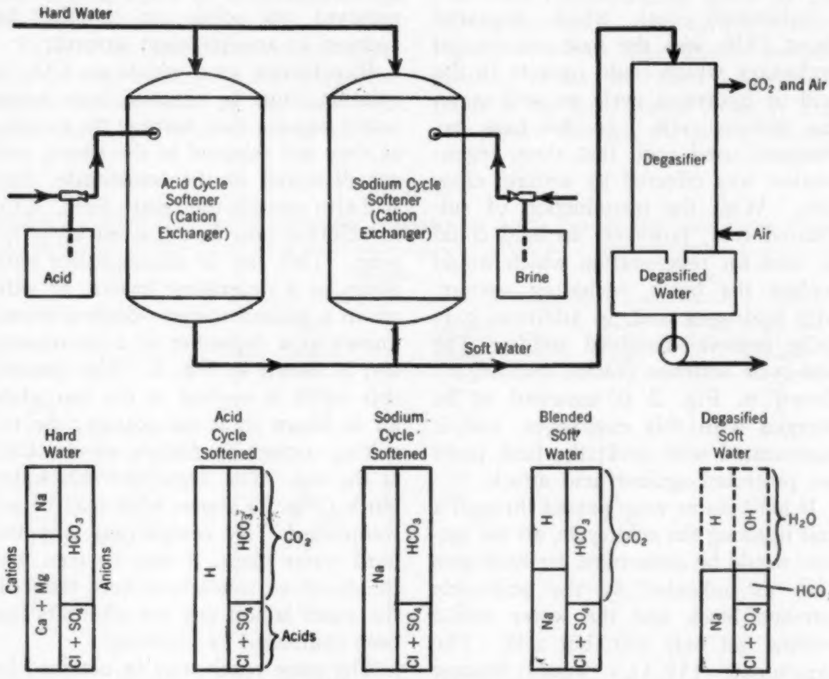


Fig. 2. Water Softening by Ion Exchange

The standard procedures for both acid-cycle and sodium-cycle softening are outlined. The composition of the original hard water and of the waters softened by each process is indicated in the lower blocks.

weaker basic cations, calcium and magnesium, are replaced by sodium, making the water soft. When the exchanger's capacity to remove hardness has been exhausted (the breakthrough point), it can be regenerated with common salt and its ability to soften thereby renewed. The stronger so-

ficially prepared siliceous-sodium aluminum silicate (1924), by sulfonated coal and shale (1936), by phenol formaldehyde resins (1940) and by nonphenolic styrene base resins (1946). Other ion exchange materials will undoubtedly be added to this series in the future.

It should be remembered that the sodium cycle softens water by exchanging the hardness-producing ions of calcium and magnesium for those that do not produce hardness, such as sodium, but that solids in solution are not reduced.

Acid-Cycle Exchange

Sulfonated coal, which appeared about 1936, was the first commercial exchanger which could operate in the acid or hydrogen cycle as well as on the sodium cycle. In the base exchangers used until that time, regeneration was effected by sodium chloride. With the introduction of sulfonated coal, however, an acid could be used for regeneration which would replace the bases, including sodium, with hydrogen and, in addition, partially remove dissolved solids. The acid-cycle softener (cation exchanger) shown in Fig. 2 is assumed to be charged with this exchanger, and is regenerated with acid; the tank parts are protected against acid attack.

If hard water were passed through a unit utilizing the acid cycle, all the cations would be exchanged for hydrogen (H) as indicated by the acid-cycle softened block and the water would become not only soft, but acid. The bicarbonate (HCO_3) would become carbonic acid (H_2CO_3), or CO_2 in solution; the chloride (Cl) ions would become hydrochloric acid (HCl), and the sulfate ions (SO_4), sulfuric acid (H_2SO_4). As acid water cannot be used for boiler feed or other purposes without first being neutralized, the feed would have to be split and the soft water effluents from both the acid and sodium cycle units blended.

The blended soft water block shows the result of this process. Sufficient sodium-cycle water containing alkalinity (sodium bicarbonate has been used as an example) has been blended to neutralize the acids by converting them to sodium chloride (NaCl) and sodium sulfate (Na_2SO_4), leaving some excess alkalinity as sodium bicarbonate ($NaHCO_3$).

The hydrogen and bicarbonate ions are not in the form of solids, but of a gas, in solution. As the gas can be removed, the solids can in effect be reduced by an equivalent amount.

Bicarbonate ions, which are CO_2 in solution, must be removed from boiler water because they corrode the metals; as they are released in the steam, and are dissolved in the condensate, they will also corrode the return lines. CO_2 in solution may be removed by stripping. This can be accomplished with steam in a deaerating heater, or with air in a packed tower. Such a tower, known as a degasifier or a decarbonator, is shown in Fig. 2. The blended soft water is applied at the top while air is blown in at the bottom; the resulting contact discharges air and CO_2 at the top. The degasified soft water block (Fig. 2) shows what may be accomplished. By comparison with the hard water block, it may be seen that the dissolved solids have been reduced, the water is soft and the alkalinity has been controlled by blending.

The same result may be obtained by neutralizing the acid-cycle softened water with an alkali. Although this method is usually somewhat more costly, it is frequently possible to reduce the investment, especially in small installations, by eliminating the need for sodium-cycle softeners.

At the du Pont plant in Clinton, Iowa, it was determined that a dissolved solids content of more than 200 ppm. in the process water could not be tolerated in the manufacture of cellophane; a water similar in analysis to the water used at the du Pont Buffalo

plant was needed. As both the river and well waters of Clinton were too high in dissolved solids concentration, Clinton could not be considered a suitable location for a cellophane plant unless this disadvantage were overcome. Experiments in split-feed processing were undertaken and management was shown what could be accomplished by this method.

Table 1 compares Buffalo and Clinton raw water analyses and gives the results accomplished by the split feed processing of Clinton water in an ex-

The disadvantage of the Clinton site was thus overcome. The cellophane plant would undoubtedly have been built elsewhere had this reduction in solids not been possible.

Ion exchange, up to this point in the exchange process, has not removed anions but has only transformed them into their corresponding acids by replacing the cations with hydrogen ions. Figure 3 shows how this is accomplished. First, the hard water analyzed in the hard water block in Fig. 2 is passed through the acid-cycle cat-

TABLE 1

Analyses of Water Softened for Cellophane Production at the du Pont Buffalo and Clinton Plants

Typical Analyses	Buffalo		Clinton	
	Raw (River) Water	Filtered, Na-Cycle Softened	Raw (Well) Water	Hydrogen and Na-Cycle Softened
	ppm.	*ppm.*	*ppm.*	*ppm.*
pH	8.2	7.6	7.9	7.4
Hardness ($CaCO_3$)	122	0	188	0
Alkalinity ($CaCO_3$)	91	84	274	21
Chlorides (Cl)	27	29	64	62
Sulfates (SO_4)	26	26	60	56
Iron (Fe)	.25	.10	.45	.15
Total Solids	190	175	356	170
Color	1	0	<10	<5
Turbidity	10	0.1	< 1	<1

changer operating on the sodium and hydrogen cycles. In both plants, the water was softened. At Clinton the alkalinity was reduced from 274 to 21 and thereby controlled. Chlorides and sulfates were of no significance in either plant, and iron was suitably reduced. Total solids at Clinton were reduced from 356 to 170, which compares favorably with the filtered sodium-cycle softened water of 175 at Buffalo. The pH was also stabilized at 7.4 by the split cycle method of controlling alkalinity.

ion exchanger, which converts it to the substance shown in the acid-cycle softened block. All the cations are replaced by hydrogen and the corresponding acids formed; the silica is converted into silicic acids. When the effluent from an acid-cycle cation exchanger is passed through an anion exchanger, the cations and anions should both be removed.

Anion Exchanger

The introduction of the anion exchanger was a revolutionary advance,

for it made it possible to remove chloride and sulfate ions and replace them with OH (hydroxyl) ions. In other words, the anion exchanger removes the mineral acids from water. This is done by passing the effluent from the acid-cycle cation exchanger through a weakly basic anion exchanger which water. Soluble silica is the only solid left dissolved in this water. The manufacturer of this type of exchanger will usually guarantee a maximum of 5 ppm. of solids in addition to the silica. Where exceptionally good quality is desired, double demineralization is sometimes employed. In this process

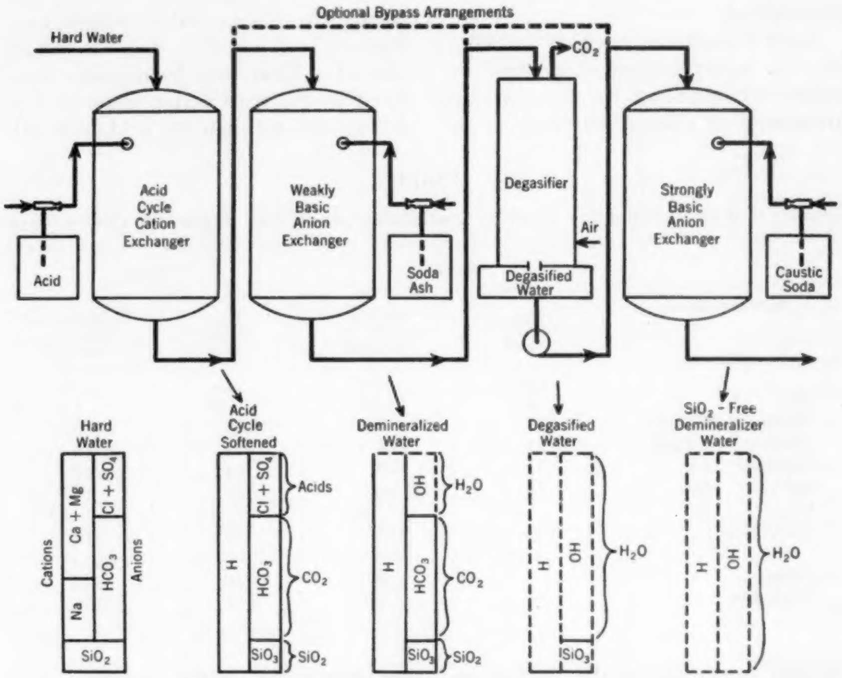


Fig. 3. Demineralization of Water by Ion Exchange

The standard procedure for demineralization of hard water is outlined. Either or both of the intermediate steps indicated by the dotted line may be bypassed, depending on the need for economy and on the relative proportions of the various cations present in the hard water.

is regenerated with soda ash. The results are shown in the demineralized water block in Fig. 3. Because the ordinary anion exchangers are too weakly basic to remove weak acids, the carbonic acid and silica (SiO_2) remain in solution. This is demineralized water, sometimes known as deionized two sets of two-bed demineralizers (one acid cycle and one weakly basic) are used in series, the second set being designed to remove ions missed by the first. With double demineralization, the manufacturer will generally guarantee an approximate maximum of 2 ppm. of total solids, excluding silica.

If the carbon dioxide content cannot be tolerated for the use to which the demineralized water is to be put, it may be removed by the degasifier. Here again, the only solids remaining in the water, except for traces which may have slipped by the deionization process, are the dissolved silica.

Because silica may be objectionable for use in high-pressure boilers or other special processes, it must be removed from water used for these purposes. An older method of removing silica consists in adding sodium fluoride to the raw water, mixing it with the influent to the cation exchanger, and, by the same process that applies to all the other dissolved solids, converting it to its corresponding acid, which happens to be hydrofluoric acid. Hydrofluoric acid reacts very readily with silica to form fluosilicic acid (H_2SiF_6), a strong acid which can be removed by a weakly basic anion exchanger. Thus by adding sodium fluoride to the raw water, it is possible, without leaving any traces of sodium fluoride in the final product, to reduce silica to a small portion.

Improved methods of producing demineralized water and simultaneously removing all of the silica content have recently been developed. Strongly basic anion exchangers which will remove all anions from the water are now commercially available. They will remove not only the mineral acids but also the carbonic acid and the silica or silicic acid. The usual arrangement of this equipment is shown in Fig. 3; the strongly basic anion exchanger must be regenerated with caustic soda, as the resin is a stronger base than the soda ash which can be used with the weakly basic exchanger.

In this process, the cation exchanger removes the cations, the weakly basic anion exchanger removes the mineral acids, the degasifier removes the carbonic acid, and the strongly basic anion exchanger removes the silica. This is not always the most economical arrangement, and, as indicated by the dotted line at the top of Fig. 3, either or both of the two intermediate steps may be bypassed. Which arrangement is used will depend on the economics involved and on the relative proportions of the various cations present in the hard water.

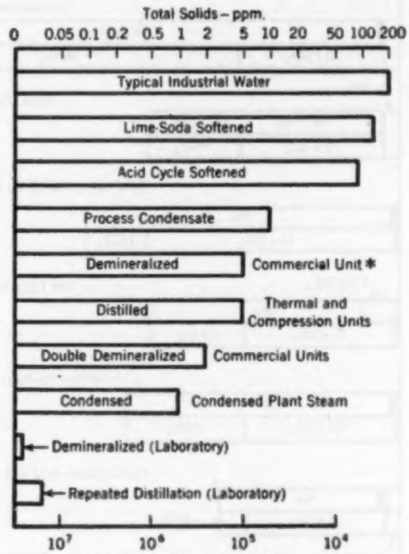


Fig. 4. Dissolved Solids Content Following Various Water Treatments

The dissolved solids content remaining in a typical industrial water will vary, depending upon the various treatment processes used.

For example, in a small laboratory installation, where elaborate equipment is not justified, the effluent from a cation exchanger may be passed directly through a strongly basic anion exchanger, which will remove all of the anions. The drawback to this sim-

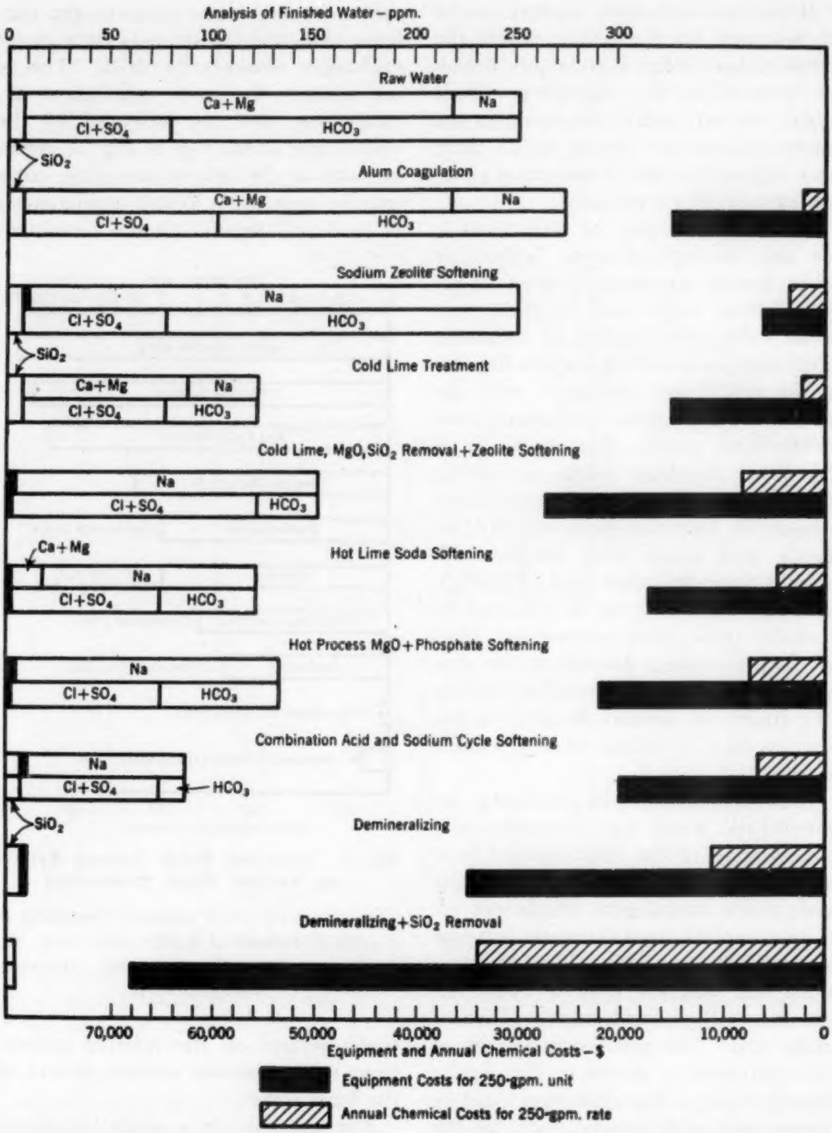


Fig. 5. Chemical Costs and Equipment Required for Various Water Treatments

The effects on chemical composition of the various types of treatment applied to water are indicated by the bars extending from the left, to which the scale at the top of the figure applies. A rate of 250 gpm. and a raw water containing 250 ppm. of solids were used to make these determinations.

TABLE 2

Typical Analyses of Condensates, Distilled and Demineralized Waters

Plant and Process	Raw Water	Finished Water		Elements*
	Total Solids	Silica (SiO_2)	Solids (Excl. SiO_2)	
	ppm.	*ppm.*	*ppm.*	
Belle				
Single Distilled	140	0.27	7.8	Si, Ca, Fe, Zn, Al, Ti, Mn, Mg, Cu, Ba, Na, Ni, Zr, Pb, Cd, Sn, Cr
Demineralized by Works	140	6.7	7.9	Si, Ca, Zn, Mg, Mn, Al, Na, Fe, Ti, Ba, Ni, Cu, Cr
Demineralized by Experiment Station	140	6.6	2.5	Si, Fe, Ca, Mg, Al, Na, Zr, Ti, Mn, Ba, Ni, Cu, Zn, Pb, Cr, Ag
Sabine R.				
Single Distilled	100	0.27	7.3	Si, Ca, Al, Mn, Fe, Mg, Na, Cu, Zr, Zn, Ti, Pb, Ba, Ni, Sn, Mo, Ag, Cr, Li
Demineralized by Works	100	8.4	6.2	Si, Fe, Ca, Mg, Ti, Al, Ba, Mn, Na, Zn, Pb, Sr, Ni, Cu, Li, Cr, Ag
Chattanooga				
Compression Distilled	95	0.038	2.0	Si, Ba, Fe, Ca, Mg, Cu, Al, Mn, Ni, Ti, Zn
Seaford				
Turbine Condensate	50	0.05	1.85	Si, Mg, Al, Ca, Ti, Fe, Mn, Or, Cu, Zn, Na, Ni, Ba, Ag
Factory Condensate	50	0.80	51.1	Si, Fe, Al, Ca, Mn, Mg, Cu, Ba, Na, Ni, Cr
Demineralized by Experiment Station	50	10.8	7.3	Si, Fe, Ca, Mg, Al, Ti, Mn, Ni, Cu, Zn, Na, Cr, Pb, Ba, Sr
Waynesboro				
Laboratory Distilled	65	0.4	2.0	
Semi-Works Distilled	65	0.6	2.0	
Demineralized	65	12.8	4.0	
Washington				
NaF Demineralized	350	0.2	4.3	
Toledo Elchem				
Demineralized	350	1.2	4.7	

* In order of apparently decreasing concentration, as found by emission spectography.

ple arrangement is that it is more expensive to remove anions with a strongly basic anion exchanger, which requires an excess of caustic soda for its regeneration, than it is to remove most of them by intermediate treatment with a weakly basic anion exchanger and degasifier. If a water contains a large proportion of alkalinity, for example, it would probably be more efficient to remove the alkalinity in a degasifier than attempt to remove it in a strongly basic anion exchanger after its conversion to carbon dioxide.

Optimum design, therefore, depends on several variables.

At the top of Fig. 4, illustrating typical dissolved solids contents produced by various exchange treatments, is represented a typical industrial water, containing 200 ppm. of dissolved solids. With acid-cycle softening followed by strongly basic anion exchanger were used, however, the silica could be reduced to such an extent that the total solids in the demineralized water, including silica, would not exceed 5 ppm. The next bar indicates the results which can be obtained with commercial four-bed or double demineralization.

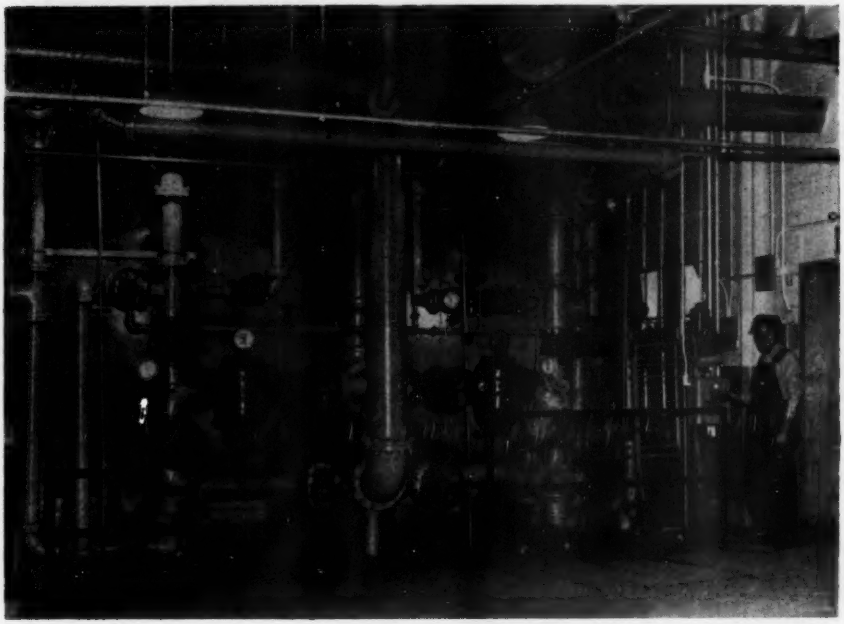


Fig. 6. Greensand Water Softeners

The tanks of the softeners at the du Pont plant in Buffalo are installed in a horizontal position. Hand valves are used to control the operation of the tank on the left; the tank on the right is controlled semi-automatically.

neutralization or blending with sodium-cycle softened water, it would be possible to reduce the solids to about 100 ppm. Commercial two-bed demineralization, using a weakly basic anion exchanger, would reduce the total solids to 5 ppm. or less, not including silica which would pass through this type of demineralizer unchanged. If a The next to last bar on Fig. 4 represents the best quality demineralized water which, to the author's knowledge, has ever been produced.

Pure Water

The chemical analysis of very pure water presents a difficult problem. To obtain reliable and reproducible indica-

tions of total dissolved solids which fall below a few parts per million is difficult, if not impossible, by chemical means. An accurate measure of the ions present in solution can be obtained by measuring the electrical resistivity of the water. Traces of impurities can be readily detected by a definite decrease in the resistivity of the water.

How the purity of deionized or demineralized water compares with that obtainable by other methods, such as distillation, is a question frequently asked. Typical results of some of the other methods of treatment are shown in Fig. 4.

Sources of pure water include not only demineralized water, but process condensate, thermally distilled water, compression distilled water and condensed steam. Purity varies widely in different installations, but results which are reasonably typical are shown in Fig. 4.

Results obtained at the du Pont plants indicate that deionized or demineralized water is the equivalent of carefully distilled water for most operations requiring water of exceptional purity. Typical water analyses of condensates, and of distilled and demineralized waters which have been obtained at the du Pont plants, are shown in Table 2.

Single-distilled waters, demineralized at the plants and at the experimental station, compare favorably with each other. Compression distillation at Chattanooga shows 2 ppm. of solids remaining with only 0.38 ppm. of silica. The turbine condensate at Seaford is similar and the demineralized unit at Waynesboro is also close. In all of these processes, it should be noted that most of the elements found in the raw water also appear in the finished water in greatly reduced quantities; it is a delusion to think that these are totally removed. This is shown by the emission spectrography results in the last column of the table.

TABLE 3

Effect of Exchange Capacity on Installed Cost of Large Sodium-Cycle Softeners

Type of Exchanger	Raw Water Hardness	Exchanger Capacity *kgr./cu.ft.*	Installed Cost *\$/kgr. $CaCO_3$ Removed*
Greensand	Low	2–3	10–17
High Capacity Greensand	Low	5–6	7–5
Synthetic Siliceous	High	9–12	5–10.5
Sulfonated Coal	Intermediate	7–9	7–10.5
Phenolic Resin	Intermediate	8–10	7–12
Phenolic Resin	High	11–16	6–10.5
Nonphenolic Resin	Very High	22–30	3.8–6.8

Rating Exchangers

Because exchangers vary in their ability to exchange ions they are compared on the basis of their exchange capacity expressed in grains per cubic foot. This measure dates back to the time when base exchange was first used for water softening and hardness of water was measured in grains per gallon (gpg.) of calcium carbonate. Expressing water analyses in grains per gallon is now almost obsolete. In this usage, however, if 1 cu.ft. of ex-

changer is capable of exchanging 1 kilograin (1,000 grains), it would soften 1,000 gal. of water containing 1 gpg. (17.12 ppm.) of hardness. Or, if the water contained 10 gpg. (171.2 ppm.) of hardness, the same amount of exchanger would soften 100 gal. There are other ways of expressing cubic foot measure in designing and comparing exchangers.

The rate is expressed in gallons per minute per square foot. The greensands are rated at 2 to 3, sulfonated coal at 5 to 7, and some of the latest styrene base resins as high as 10 gpm. per sq.ft.

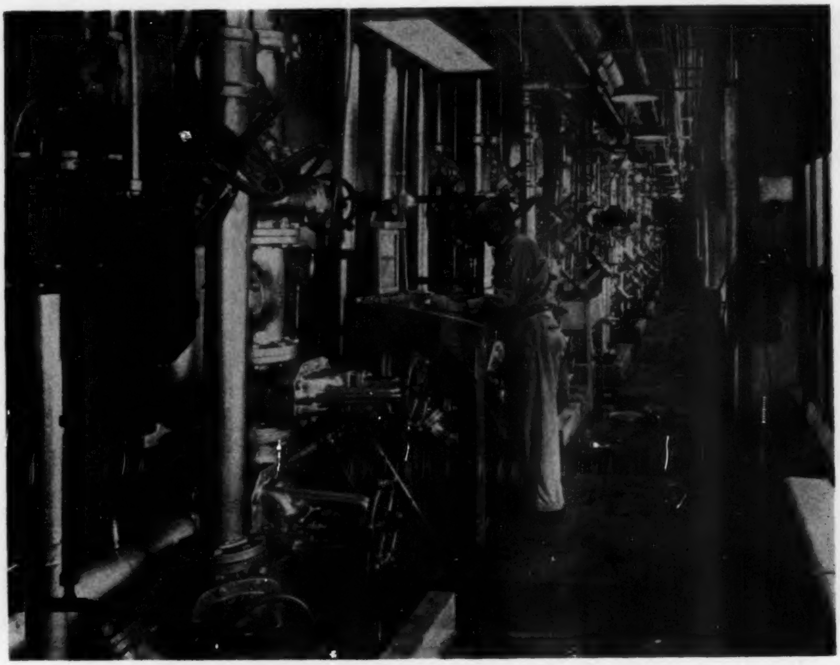


Fig. 7. Horizontal Water Softeners at Spruance Plant

A battery of ten horizontal water softeners is operated on the sodium cycle in the Spruance plant, Richmond. The total processing capacity of these softeners is approximately 10 mgd.

this relationship, such as in pound equivalents per 100 cu.ft., but kilograins of $CaCO_3$ per cubic foot is a convenient figure to use in selecting exchangers and equipment. Although water analyses are usually expressed in ions, they are converted to equivalents of calcium carbonate in order to facilitate the use of a kilograin per

Table 3 shows the effect of exchange capacity on the installed cost of large sodium-cycle softener installations. These figures were obtained from one of the vendors and, like all such figures, must be taken with some reservations. They do, however, show the trend. It is to be noted that greensands of 2 to 3 kilograin capacity have

an installed cost of $10 to $17 per kilograin removed. The higher capacity exchangers—nonphenolic resins rated at 22 to 30 kilograins—range as low as $3.80 to $6.80 per kilograin removed. It is also possible to increase the rate of flow as the capacities are increased. Both these factors tend to reduce investment in both the amount of exchanger necessary to treat a certain quantity of water and the size of the tank required.

Cost

The design engineer has such a range of capacities and rates to consider that each problem must be investigated and solved according to individual circumstances on the most economical basis. Water analysis, exchange capacity and size of equipment must all be considered.

Information developed from data supplied by a vendor is shown in Fig. 5 and applies to a flow of 250 gpm. and to dissolved solids of 250 ppm. It should be noted that as the ions are exchanged and solid concentration is reduced the cost of equipment as well as the operating cost increases. There are some exceptions to this rule, but generally speaking it is valid.

A study was made at the du Pont plant in Seaford, Del., to determine the

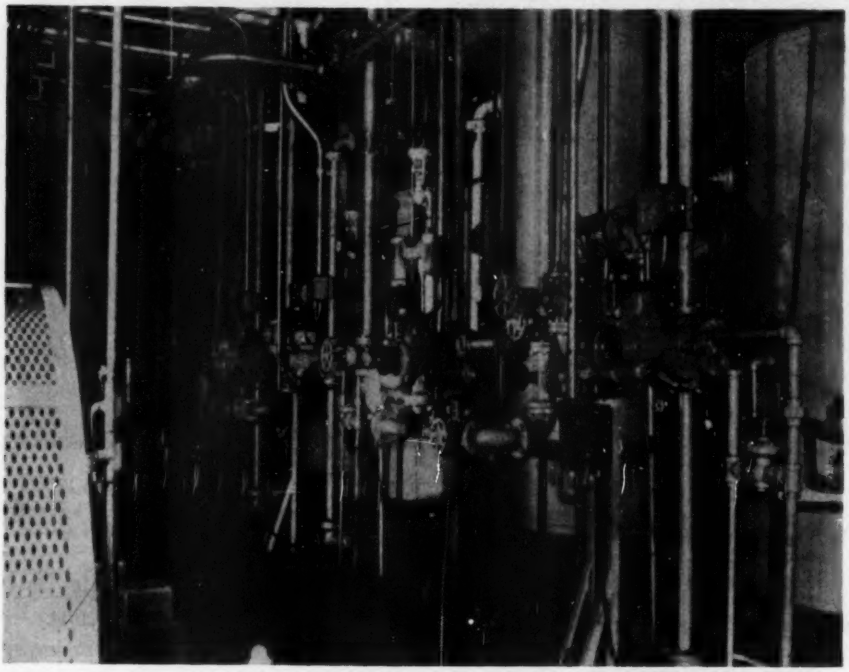


Fig. 8. Demineralizing Installation at Washington Plant

The installation comprises two groups with two units in each. The groups, each of which is rated at 60 gpm., are operated alternately. The tall tank functions on the acid cycle; the shorter tank is the weakly basic anion exchanger.

cost of a number of methods designed to reduce the quantity of dissolved solids in the water. Table 4 summarizes the results of this study, indicating that of the three methods studied—compression distillation, a one-effect still and demineralization—demineralization offers the cheapest cost for each gallon per minute of capacity is $7,500, $5,250 and $1,310; total investment is $8,900, $6,700 and $1,370. The operating cost per 1,000 gal. treated is $1.48, $1.81, and $0.44.

It might be asked why these large differences in investment and operating cost exist. The answer appears to

TABLE 4

Cost Comparison of Treatment at the Seaford Plant

	Compression Still	Ordinary Still	Demineralizer
CAPACITY			
Number of units	4	4	2
Capacity per unit, *gpm.*	6.7	8.3	13.3
Total capacity, *gpm.*	26.6	33.3	26.6
INVESTMENT			
Equipment cost	$ 97,800	$ 75,820	$12,800
Installation cost	102,200	99,180	22,200
TOTAL COST*	$200,000	$175,000	$35,000
Allocated facilities	37,450	48,150	1,450
TOTAL INVESTMENT	$237,450	$223,150	$36,450
ANNUAL OPERATING COST†	$ 20,680	$ 25,350	$ 6,120
TOTAL COST PER GPM.	$ 7,500	$ 5,250	$ 1,310
TOTAL INVESTMENT PER GPM.	$ 8,900	$ 6,700	$ 1,370‡
OPERATING COST PER 1,000 GAL.	$ 1.48	$ 1.81	$ 0.44

* Order of magnitude estimate.
† Exclusive of depreciation and maintenance costs, on a basis of 14-mil.gal. production annually.
‡ Could be reduced 50 per cent by installation of a filter.

means of reducing the solids content of the water.

Whereas the total investment cost of compression distillation and a one-effect still is over $200,000, the cost of a demineralizer is approximately $36,450. The annual operating cost for treating 14 mil.gal. per year is: $20,680 for compression distillation, $25,350 for distillation and only $6,100 for demineralization. The operating

be that, in distillation, the total quantity of water must be treated, whereas in ion exchange only the dissolved substances are treated. Both processes are applicable to waters of high solids content; however, the treatment of such water by ion exchange is prohibitively expensive, and the break-even point is from 1,500 to 2,000 ppm., depending on the kind of solids present.

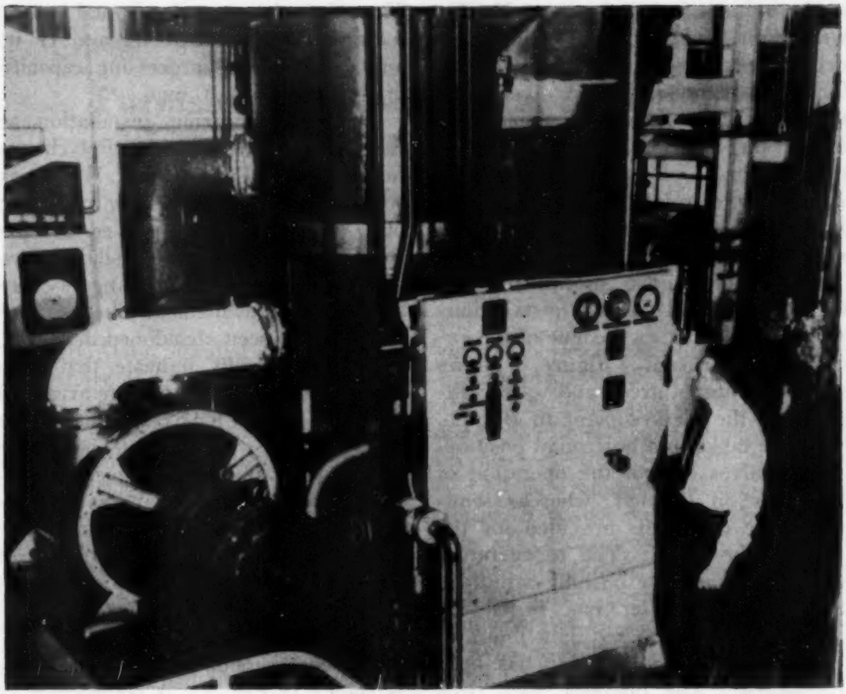


Fig. 9. Compression Still at Chattanooga

Despite its impressive size, an output of only 7.4 gpm (465 gph.) of demineralized water is produced by this apparatus.

Design Problems

The engineer confronted with the problem of design must consider the nature of the ions dissolved in the water as these are revealed by chemical analysis, and must tailor the apparatus to fit. The greater the number of ions to be removed, the greater the capacity which must be provided to remove them. A water in the East may contain approximately 100 ppm. of ions expressed as $CaCO_3$, whereas the water at Clinton, Iowa, would have about 400 ppm. Clinton water would consequently require four times as much exchanger of the same capacity. As the rate of 100 gpm. would be approximately the same for both exchangers, the tank at Clinton would have the same diameter but in theory, at least, be four times as high.

Chemical analysis also informs the engineer of the relation between the ions. With a water having no Cl or SO_4 ions, all the cations would be bicarbonate; and thus a cation exchanger on the acid cycle would demineralize the water, and no anion exchanger would be needed. If Cl and SO_4 ions are high in relation to the HCO_3, then more Na cycle capacity is needed to neutralize the mineral acids, and a larger tank will be required. The greater the bicarbonate (HCO_3)

in the influent water, the more H_2CO_3 will result, and the larger will be the degasifier required to remove it. Similarly, in demineralization, the more ions which must be exchanged, the bigger the apparatus must be to exchange them. Up to about 1,500–2,000 ppm. of solids, depending on the ions, the cost of ion exchange is uneconomical compared to distillation.

The photographs shown in Fig. 6–9 are of actual du Pont installations and afford examples of some of the exchangers discussed. Figure 6 shows an installation of greensand water softeners at the Yerkes plant in Buffalo, with the tanks in a horizontal position. Hand valves control the operation of the tank on the left, whereas semiautomatic control is provided for the one on the right. The regenerating cycle is initiated by pushing a button; after the exchanger has rinsed for about 30 minutes, a red light indicates that the regenerating cycle has been completed. The operator then tests the water's softness and presses another button, putting the softener into operation. The Yerkes plant has several units totaling around 4,000 gpm. Five of them are hand controlled; the other two are semi-automatic.

Figure 7 shows a battery of ten horizontal water softeners on the sodium cycle at the Spruance plant in Richmond. Several years ago, it was necessary to increase the rate of water softening at this plant to provide an increase in production. Comparative cost estimates indicated that the most economical way to accomplish this was to remove the greensand from the softeners and replace it with a carbonaceous zeolite. Softening was increased in this manner from 5 to 7 gpm. per sq.ft. and the thickness of the bed was reduced from 54 to 36 in. The plant has ten horizontal water softeners 9 ft. in diameter and 17 ft. long, with a total processing capacity of approximately 10 mgd.

The demineralizing installation at the Plastics Division of the Polychemicals Dept. in Parkersburg, W.Va., is shown in Fig. 8. This fully automatic plant was originally installed for the sodium fluoride removal of silica before strongly basic anion exchangers were commercially available. The removal of silica has been abandoned, however, as process results indicate that it is not necessary. The tanks are arranged in pairs; the tall tank operating on the acid cycle, the shorter one being the weakly basic anion exchanger. No degasifier was installed as it was not necessary to remove carbon dioxide. The installation comprises two groups of two units each; each group is rated at 60 gpm. per sq.ft. and they are operated alternately.

The compression still at Chattanooga is shown in Fig. 9. A comparison of this apparatus, producing 7.4 gpm. (465 gph.) of softened water, and the units in Fig. 10 may indicate why a difference in investment costs exists in producing water of similar quality.

It should be noted that no demineralized water is used for boiler feed except at the Toledo, Ohio, plant. At this plant it was considered more economical to increase the size of the demineralized water unit to provide boiler feed than to install water softening equipment. Du Pont's experience in general has shown that it is more economical to soften water and chemically treat the residual hardness than it is to install an apparatus for demineralizing it. Although the picture may change at some later date, this represents the current approach to the problem.

Furnishing Chicago Water to Outlying Municipal Districts

By Loran D. Gayton

A paper presented on March 30, 1951, at the Illinois Section Meeting, Chicago, Ill., by Loran D. Gayton, Asst. City Engr., Dept. of Public Works, Chicago, Ill.

CHICAGO, located on the west shore of Lake Michigan and taking its water supply directly from that body of water, is blessed with a practically inexhaustible source of supply. Lake Michigan is 307 miles long and 118 miles wide, with a maximum recorded depth of 923 ft. The water surface of the lake covers an area of 22,400 square miles, and it has a drainage area of 69,040 square miles. Rainfall is well distributed throughout the year, averaging 32 in. annually.

During its early history, Chicago's sewage was delivered either directly into Lake Michigan, or into the Chicago River, which then flowed into the lake. As the population and the industries of the city increased, with a consequent increase in sewage discharge, the water supply became dangerously contaminated.

For many years there was a great deal of discussion about the best method of securing permanent relief from the scourge of typhoid, and in 1885 the city of Chicago created a Drainage and Water Supply Commission to investigate thoroughly the entire subject of water supply, sewerage and drainage.

Chicago Sanitary District

In 1887 the commission issued its report. After considering every known method of sewage disposal and also the great demand for a deep waterway to the Gulf of Mexico the commission made the following recommendations to overcome Chicago's difficulties:

1. That a sanitary and ship canal be constructed, connecting Lake Michigan at Chicago with the DesPlaines River at Lockport, of sufficient size and capacity to permit a flow of 24,000 cfm. of water for each 100,000 of population, based on a total of 2,500,000 people.

2. That the canal be constructed of such a depth, and so connected with the Chicago River, as permanently to reverse it and send its flow through the DesPlaines and Illinois into the Mississippi River.

This report was immediately sent to the War Dept. and the Congress by the Division Engineer at Chicago.

As the work of constructing the canal was estimated to cost not less than $28,000,000, and as it would be necessary to issue bonds for immediate construction, it was evident that the city, which had already reached its limit of bonded indebtedness, could not carry out the work. Recourse was had to the legislature, and in 1889 a new entity, the Sanitary Dist. of Chicago, was formed and empowered to levy a tax, to issue bonds and to construct the canal. The boundaries of the district

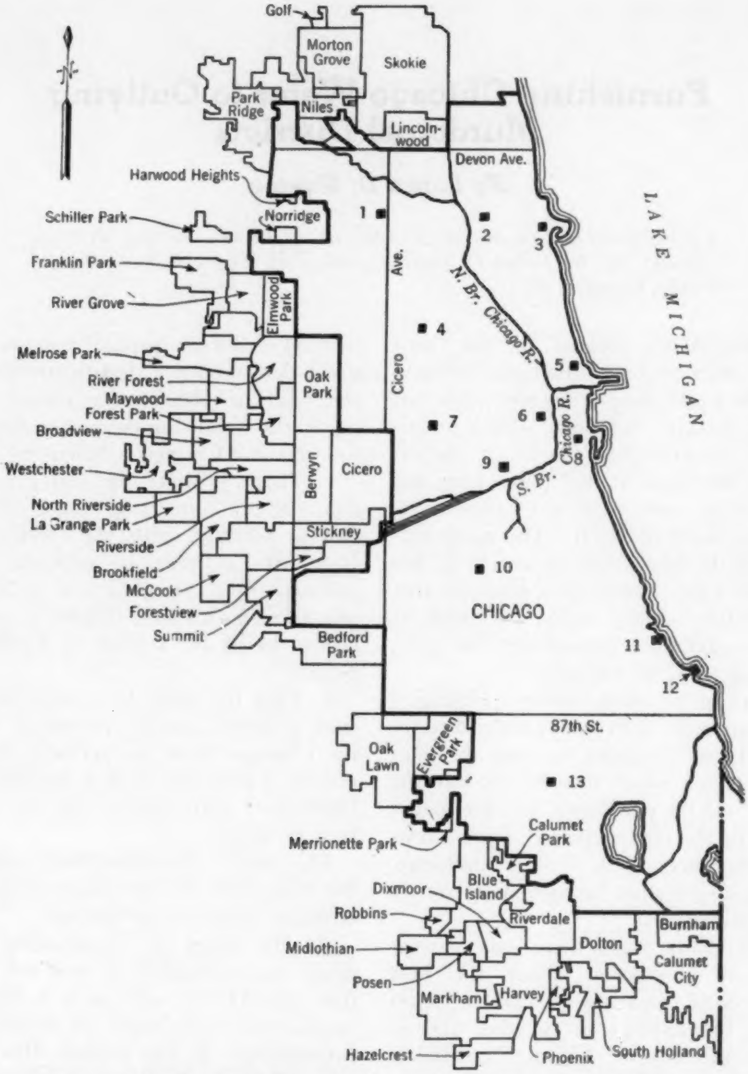


Fig. 1. Municipalities Supplied From Chicago Water Works System

The key to the numbering system is given below:

1—*South District Filtration Plant*
2—*Mayfair Pumping Station*
3—*Thomas Jefferson Pumping Station*
4—*Lake View Pumping Station*
5—*Springfield Pumping Station*
6—*Chicago Pumping Station*
7—*Cermak Pumping Station*
8—*Central Park Ave. Pumping Station*
9—*14th St. Pumping Station*
10—*22nd St. Pumping Station*
11—*Western Ave. Pumping Station*
12—*68th St. Pumping Station*
13—*Roseland Pumping Station*

were not coincident with the city limits, but stopped at 87th St. on the south, at Devon Ave. on the north, and included a large part of Cicero on the west. Work on the canal was started in 1892; it was completed and put into operation on January 2, 1900.

With the construction of the drainage canal, the city blocked all sewers draining into Lake Michigan, and built a system of intercepting sewers to divert all sewage from the lake to the canal.

The Sanitary District of Chicago has grown from an initial area of 185 square miles, and a population of 1,150,000, to 470 square miles in which there are 71 municipalities, including Chicago, and a total population of 4,380,000. Under the Sanitary District Law, the city of Chicago must, upon demand, supply water to any municipality within the district limits which brings its pipeline to the Chicago city limits. The price charged must be the same as that paid by large users of water within Chicago.

The first municipality to take advantage of this provision was Burnham, which signed a contract with Chicago in 1909. At present, Chicago supplies water directly to 37 municipalities in the Chicago Sanitary District. A number of the municipalities taking water directly from the Chicago system supply Chicago water to eleven other municipalities in the Sanitary District. As a result, Chicago water is now used by 48 municipalities, with an aggregate population of 486,284, which are in the Chicago Sanitary District (Fig. 1).

Proposed Extension

In August 1947, Oscar E. Hewitt, Chicago's Commissioner of Public Works, made public a plan showing a proposed extension of the Chicago Water Supply System which would supply Lake Michigan water to 62 municipalities in the Chicago metropolitan area now depending upon ground water supplies (Fig. 2). The plan was the result of studies made by the Bureau of Engineering over a number of years.

The municipalities to be served extend on the north from Barrington on the north line of Cook County to Elgin, St. Charles and Aurora on the west, Joliet on the southwest, and on the south to the south line of Cook County. The system would serve Lake Michigan water to every municipality of any size in the area under consideration.

The 1940 Census counted a population of 320,548 in the 62 municipalities, and it is estimated that their 1970 population will reach 493,000. On a consumption basis of 150 gpcd., it is estimated that the maximum daily demand in 1970 will be approximately 74 mil.gal.

The system is designed to meet a maximum day's demand in 1970 and to deliver water at ground level at the boundary of each municipality. Each municipality is to provide and maintain any necessary reservoirs and pumping equipment and to distribute the water to the ultimate consumer. The water is to be metered at the point of delivery to each municipality. The system has been divided into three major zones: the Northwest, the West or Central, and the South. The required quantity of water for both the Northwest and Central zones will be available from the Chicago Ave. tunnel. An extension, 10 ft. in diameter, of the Chicago Ave. tunnel to 25th

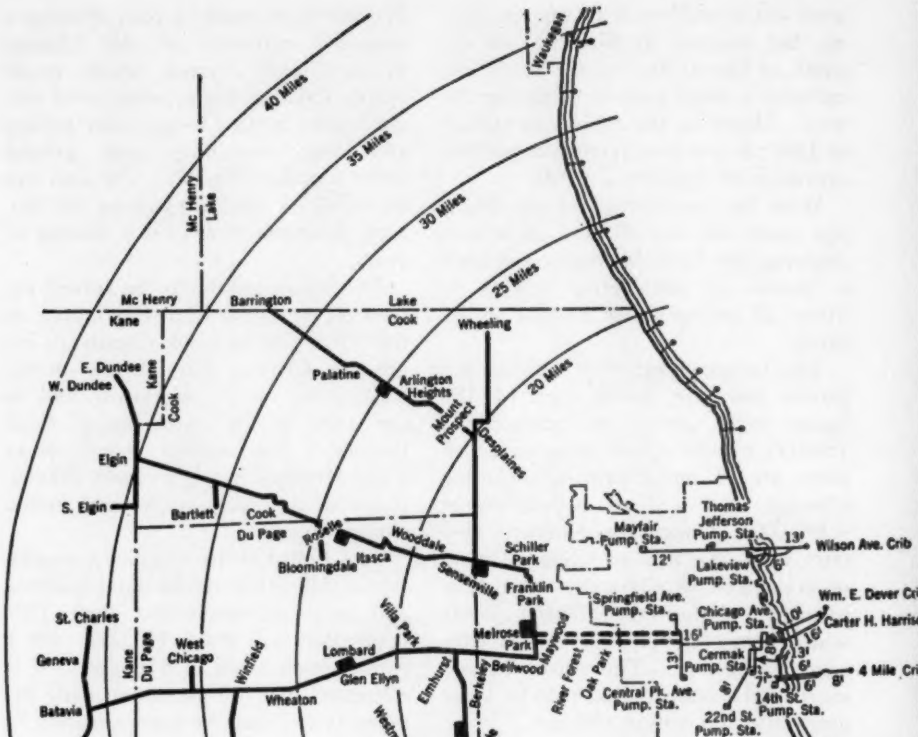
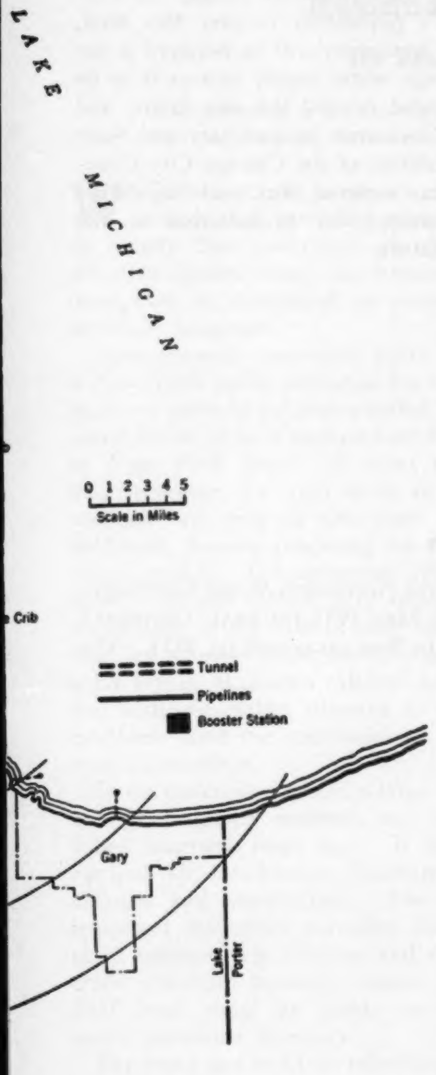


Fig. 2. A Water Supply System for the Chicago Metropol



Area

Ave. in Melrose Park is proposed. Provisions for a reservoir and low-lift pumps at the end of the tunnel have been made, so that if the peak demand by city consumers should require all the water in the tunnel for several hours the suburban system could continue to pump from the reservoir, which would be refilled during the off-peak demand.

The Northwest zone, taking water from the Chicago Ave. Tunnel, will serve nineteen communities, with an estimated population in 1970 of 111,600 and an estimated maximum-day water demand of 16.74 mil.gal. The Northwest zone will require three booster pumping stations.

The Central zone, taking water from the Chicago Ave. tunnel, will serve eighteen communities with an estimated population in 1970 of 224,600 and an estimated maximum-day demand of 33.69 mil.gal. The Central zone will require two booster pumping stations.

The South zone, taking water from the Roseland Pumping Station, will serve 25 communities with an estimated population in 1970 of 156,000 and an estimated maximum-day demand of 23.415 mil.gal.

The South zone is divided into two projects, both getting water from the Roseland Pumping Station. To increase the capacity of the station a new 12-ft. tunnel is to be built in 74th St., from Oglesby Ave. to State St. This will take its water supply from the existing tunnel at Oglesby Ave. and connect with the 10-ft. tunnel running south in State St. to the Roseland Pumping Station.

The Chicago Heights project will require a reservoir and a booster station near 151st St. and Indiana Ave. If the peak demand by Chicago's con-

sumers should require all the water available from the main, the booster could continue to pump from the reservoir, which would be refilled during the off-peak demand.

The Joliet project will be exclusively supplied by new pumps at the Roseland Pumping Station, which will deliver water at a pressure sufficient to eliminate the need for a booster station.

Preliminary cost estimates made from the drawings indicate that the metropolitan water supply system outlined could deliver Lake Michigan water to the municipalities under consideration at reasonable rates.

Legislation

Article 78 of the Cities and Villages Act gives municipalities with a population under 500,000 the power to extend their water supply systems beyond their corporate limits. As Chicago's population is over this limit, new legislation will be required if the Chicago water supply system is to be extended beyond the city limits, and the Committee on Judiciary and State Legislation of the Chicago City Council has ordered that such legislation be drafted for presentation to the legislature.

Correction

In the paper "A New Water Supply for the Alexandria Water Company" by E. H. Aldrich, which was published in the May 1951 JOURNAL, the plant's capacity was incorrectly given as 4 mgd. in the first paragraph (p. 332). The correct figure is 9 mgd.

Controlling Taste, Odor and Color With Free Residual Chlorination

By Thomas M. Riddick

A contribution to the Journal by Thomas M. Riddick, Consulting Engineer and Chemist, New York.

WATER treatment is not an exact science, but one that advances so rapidly that yesterday's standards are often obsolete today, and frequently must even be considered as previous errors in judgment.

Approximately seventeen years ago a New York jurist published his life's work—a series of volumes entitled *The Legal Status of the Common Law Wife in New York State.* A short time later, however, the legal status of the common law wife in this state was abolished, thereby rendering his life's effort obsolete. The pioneering efforts of Marconi and Edison were similarly outstanding at the time of their inception, but wireless transmission today is a far cry of Marconi's original work, and Edison's carbon filament is now worthless from the standpoint of efficient illumination.

In the water works field, a large volume of historical research was published fourteen years ago. It summarized all the known literature of chlorine and chlorination. The all-important difference currently recognized between free chlorine and combined chlorine, however, makes this 1937 book about as timely as that year's telephone directory.

The many and involved relationships governing the sterilizing power of chlorinous solutions in waters of varying pH, alkalinity, turbidity, temperature, and organic, carbonaceous and nitrogenous content were not very well understood before the government-sponsored research made during and after World War II.

This newer knowledge of the qualities and capabilities of chlorine forces us to discard many previous theories about tastes and odors.

A great deal of information is available describing the fresh water algae that cause tastes and odors. These organisms range from the relatively inoffensive Diatomaceae such as *Asterionella* and *Synedra* to the strictly offensive protozoan types such as *Dinobryon* and *Synura.* Control of these organisms, or the resulting offensive conditions created by them in open reservoirs, is conventionally attempted with some form of copper sulfate. Sometimes chlorine or activated carbon is used.

Although the types and properties of fresh water algae are well understood, less is known about the various types of aquatic weed growths which can and do produce rank tastes and odors. Nor has any practical method yet been devised for their ready removal or elimination. Efficient removal of both algae and weed growths

can be effected by the para-dichlorobenzene type of chemical. The mothball odor thereby produced, however, can sometimes be far worse than that of the algae.

Both algae and aquatic weeds undoubtedly could be successfully controlled by the newer types of weedicides in the 2,4-D group, but their use would kill off most fish. The tolerance, also, of the human organism to these chemicals has not yet been sufficiently well established to permit their general adoption with safety.

The worst offenders, the protozoa, are generally at their peak during the winter months, when reservoirs in the temperate zone are frozen over. Copper sulfate can be applied by suspended bags through holes chopped in the ice, but this is more of a token than an effective treatment.

There are, furthermore, many indications that the use of copper sulfate or other algicides in open reservoir waters tends to upset the natural biological balance created by the pattern of antagonism among classes and types of organisms, and thus conditions may be made worse rather than improved. It also seems evident that shallow areas, fluctuating water levels and the lack of steeply sloped banks in reservoirs are more fundamental causes of a poor quality of stored water, regardless of our best attempts to control either algae or weed growths.

The Problem of Topography

To achieve complete, continuous and effective control of taste- and odor-producing algae and aquatic weeds is virtually impossible. Such control depends more upon the geological terrain, the character of past and present vegetation, and the soluble mineral constituents of the overburden of the watershed than it depends upon the algicides.

The conditions which render reservoirs free from algae and weed growths can be determined from present knowledge of fundamental aquatic biology. A number of striking examples can be found in Alaska and New Brunswick, Canada. Many reservoirs there were formed by glacial action and consequently have steep, uniformly sloped sides and few shallow areas, averaging 30 to 40 ft. in depth. The watershed has few swampy areas and a relatively high degree of underground seepage keeps the water cold. Finally, the overburden contains few soluble minerals, with phosphates and nitrates especially scarce.

The opposite of these conditions creates the most favorable environment for the growth of objectionable algae and weed growths. A low, 15–30 ft. dam across a long tapering valley with gently sloped sides and with swampy areas on the smaller feeder brooks in addition to agricultural lands on the watershed, will produce sufficiently unfavorable conditions to be uncontrollable by any biological or algicidal methods known today.

The shallow areas permit penetration of sunlight with the accompanying symbiotic growths of algae and aquatic vegetation. The feeder streams supply an ever abundant source of algae for reseeding after rainfall. And the agricultural fertilizers supply ample nutritive ingredients so that these growths can flourish.

If copper sulfate is added in sufficient dosages and at sufficiently frequent intervals (doses as high as 5 ppm. have been applied with no appreciable remedial effects) to control algae even partially all fish are inevitably killed, thereby producing a biological

imbalance which fosters the growth and incidence of algae even further.

Taste and Odor Controls

Control of tastes and odors at the treatment plant is conventionally, and often successfully, attained by the application of activated carbon and by the use of ammonia. Both these treatments have been used extensively, but each has its limitations.

The application of normal dosages of chlorine, to produce residuals of about 0.3–0.6 ppm. for the purpose of disinfection is one of the basic and most frequent causes of tastes and odors. The reaction of small doses of chlorine with algae, or with the organic content of the water caused by algae or growths of vegetation, can produce tastes and odors which cannot be removed even by aeration in addition to the application of carbon and ammonia.

If it were safe to apply doses of chlorine low enough to produce no residual, or residuals of less than 0.05 ppm., then both the incidence and intensity of tastes and odors would be greatly minimized. If also the watershed were relatively uninhabited, and the raw water free from contamination, then treatment of this type might produce a finished water which would meet the U.S. Public Health Service standards. The margin of bacterial safety would be too slight, however, for the comfort of either the designing engineer or the plant superintendent, and the state departments of health would certainly not tolerate such low residuals, regardless of satisfactory laboratory results.

A few years ago free residual chlorination and superchlorination were widely adopted with varying degrees of effectiveness. It was then generally believed that this high-rate treatment was quite applicable to some supplies, but unsuited to others. It would therefore seem that the break-point process was a step in the right direction—but too short a step.

Experiments at Nyack and Ossining

The Nyack and Ossining (New York) Water Departments* have, during the past sixteen years, experimented with innumerable methods of water treatment at their plants; consequently, both plants have been materially improved.

These water works employ rapid sand filtration but differ appreciably inasmuch as a very variable river (Hackensack) water is used at Nyack, whereas a stored reservoir water of fairly constant quality is employed at Ossining.

Before 1947 treatment at both plants included aeration, coagulation, sedimentation, filtration, chlorination, ammoniation and, at times, the addition of as much activated carbon as possible.

At these plants, as in most water works that treat surface supplies, tastes and odor removal presented no great difficulties during most of the year. Particular care had to be exercised during a few months annually, and for perhaps five or ten per cent of the time complete taste and odor removal was impossible. In fact, extreme skepticism should be shown to the statement of any operator who reports that taste and odor removal from surface waters is complete at all times. Such a person probably needs a medical check of his olfactory and gustatory senses, an objective appraisal of his veracity, or perhaps, to use the current expression, to have his head examined!

In 1947 a further attempt was made at the Nyack and Ossining plants to eliminate both regularly anticipated and sporadic outbreaks of taste and

odor in the finished waters, by instituting what was then known as "breakpoint" chlorination and superchlorination. This procedure required the addition of sufficient chlorine to maintain a total chlorine residual of 0.5–1.0 ppm. in the plant effluent after a contact period of approximately four hours. Results were encouraging as a general improvement was obtained.

Within about four months, however, finished water that had rank taste and odor was discharged from the plant about a half dozen times. The severity of these outbreaks was sufficient to jeopardize the positions of both the general superintendent and the author.

Superchlorination was therefore immediately abandoned and free residual chlorination with dechlorination was instituted. This required sufficient primary dosage to obtain a residual of a full 4 ppm. of free chlorine in the filtered water after a contact of about four hours. This was then reduced by dechlorination with sulfur dioxide to about 0.3–0.4 ppm.

On the day of initial operation with the latter method at Ossining, the concentration of *Anabaena* (caused by a heavy rainfall that drained stagnant swamplands) approximated 4,000 standard areal units per ml. This concentration was great enough to be visible and the taste and odor created by either normal or superchlorination were rank. The new treatment was remarkably successful, and, with but few minor alterations, has since remained unchanged at both plants. The incidence of objectionable tastes and odors has without doubt been reduced

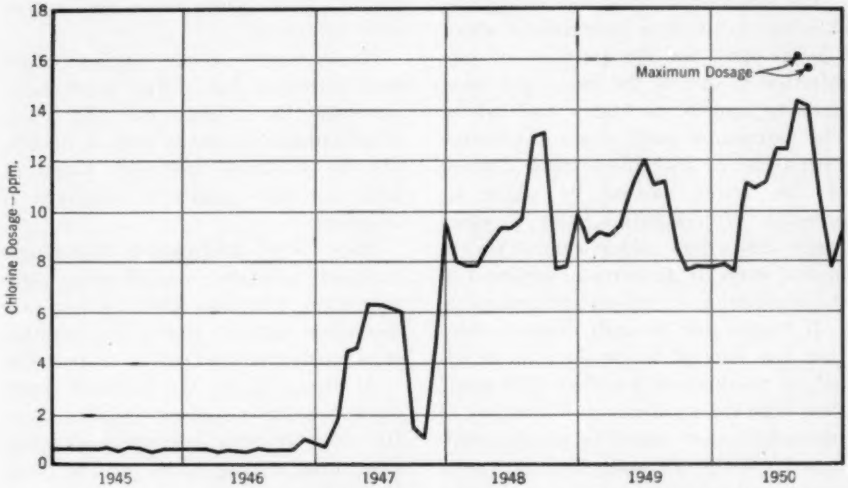


Fig. 1. Average Monthly Chlorine Dosages at Ossining Plant

During 1945 and 1946 chlorine was applied for disinfection only, with the average dosage less than 1.0 ppm. From March through August 1947, free residual chlorination was employed, requiring the addition of 6 ppm. of chlorine. Beginning in 1948, chlorine was employed as an oxidizing agent only, and dosages were increased

considerably, compared with the best operation possible when employing the older methods of treatment.

Color has been bleached from as high as 35–45 to 3–10 ppm. (averaging 5 ppm.), and turbidity has been reduced to a satisfactory level by filtration alone. Both iron and manganese have been oxidized and removed either by natural sedimentation or by the filter sand. The operator's work has treatment is now required, and, as no coagulant is employed, less alkali is necessary for corrosion control.

Chlorine dosages have varied from 8 to 18 ppm. It is noteworthy that the change in chlorine demand of a stored reservoir water can sometimes take place within a few hours, due to thermal overturns altering the characteristics of the raw water at the point of intake.

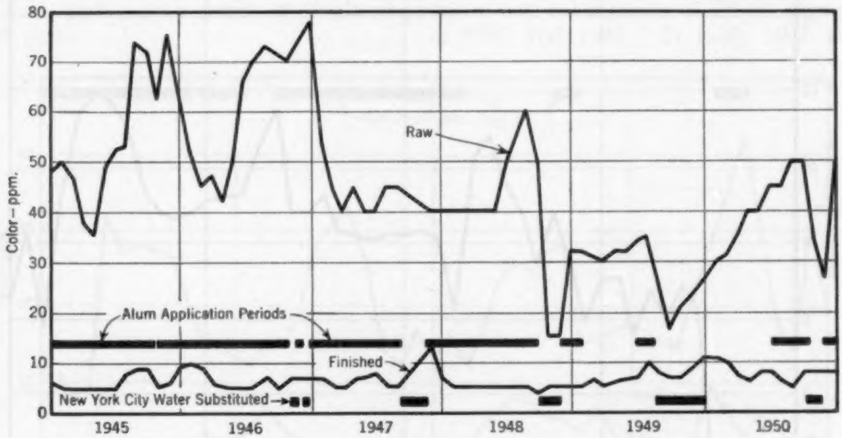


Fig. 2. Color of Raw and Finished Waters at Ossining Plant

This chart shows color in raw and finished waters, the period when alum was applied and intervals when New York City Croton Aqueduct water was used. In early 1947 a line was installed to permit blowoff of reservoir water from the bottom of the stagnation zone, effectively reducing the color of the reservoir water. Lowering of raw water color and application of high dosages of chlorine enabled the plant to operate without using alum about 90 per cent of the time.

thus been greatly lessened, as coagulation is no longer required, and filter runs have been lengthened considerably.

In addition to obtaining these benefits, both plants have operated for more than twenty of the past twenty-four months, without the addition of any primary alkali, coagulant, ammonia or activated carbon. Only one chlorination and one dechlorination

Discussion of Graphs

Results of three and one-half years of operation with the break-point process and free residual chlorination (with dechlorination) are shown in Fig. 1–4.

Figure 1 shows the chlorine dosage at Ossining, N.Y. In 1945 and 1946 chlorine was applied for disinfection

only, and the dosage averaged less than 1.0 ppm. During 1947 (March through August) free residual chlorination was employed. This required the addition of about 6 ppm. of chlorine and resulted in a residual of about 1.0 ppm. The break point was never sharply defined, although in general this residual consisted of free rather than combined chlorine. Operating results, as previously noted, were sporadic. Considerable improvement was often noted, but periods during which tastes and odor could not be controlled were too frequent to tolerate.

Beginning in 1948, chlorine was employed as an oxidizing agent only, and dosages were increased to produce a free chlorine residual of 4 ppm. after a four-hour contact. Residuals were then reduced to 0.3 ppm. by the application of sulfur dioxide.

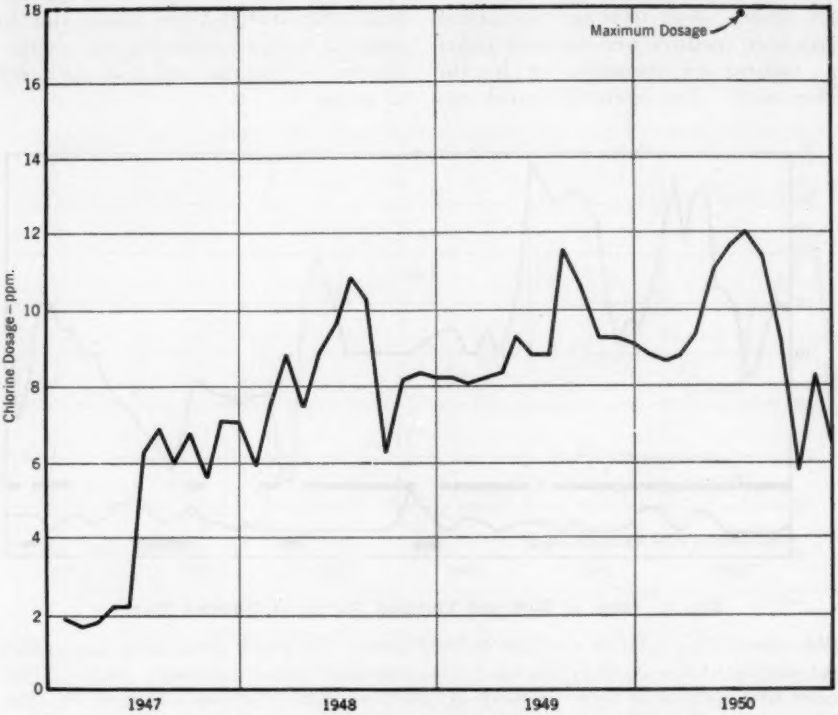


Fig. 3. Average Monthly Chlorine Dosages at Nyack Plant

The amounts fed varied, producing a disinfecting dosage of 2 ppm., a break-point dosage of 6–7 ppm. and a free residual chlorination (with dechlorination) of about 8–9 ppm. during the winter months and 12 ppm. in the summer. Maximum dosages are about 18 ppm.

Experimentation was then undertaken to reduce, if possible, the established four-hour residual of 4 ppm. All results indicated that no lower re-

sidual provides a sufficient margin of safety to produce a uniformly good water at all times. It is undoubtedly true that lower residuals (2.5–3.0 ppm.) are satisfactory at times, but such periods are unpredictable, and operation with such residuals inevitably leads to the discharge of a poor quality water. All indications point to the conclusion that the Ossining supply requires a winter dosage of about 8–10 ppm. and a summer dosage of 12–14 ppm., with peaks as high as 16 ppm.

Aeration of the raw water following chlorination is very desirable and can be done without excessive loss of chlorine after as short a contact period as ten seconds. Aeration of the filtered water is also desirable.

Figure 2 shows color in the raw and finished waters, the period when alum was applied and the intervals when New York City Croton Aqueduct water was used.

It will be observed that the raw water had color peaks of 70–80 ppm. in 1945 and 1946. In early 1947 a

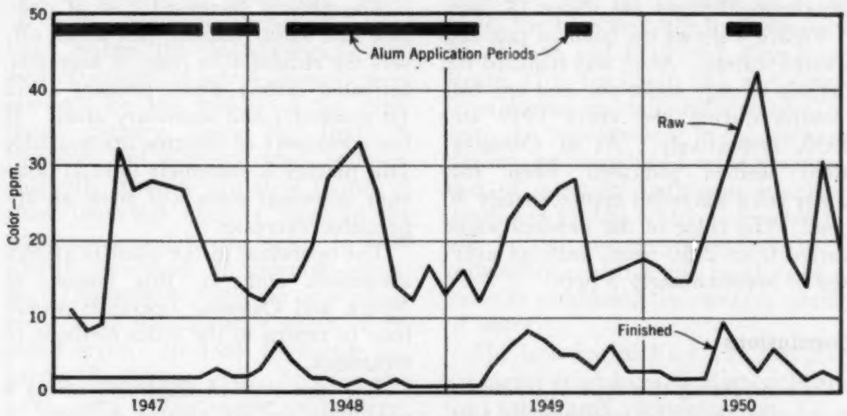


Fig. 4. Color of Raw and Finished Waters at Nyack Plant

Color of both raw and treated waters is shown. Alum was required for periods of only about one and one-half months during 1949 and 1950, and generally seemed to be needed only when raw water color exceeded 40 ppm.

Dechlorination is as important a factor to palatability as chlorination is to potability. The free chlorine residual in the plant effluent must be reduced to 0.3–0.4 ppm. Higher residuals inevitably cause complaints. In order to assure uniformity of residuals it is desirable, if not essential, to install a continuous chlorine recorder. Without this device, fluctuations in residuals due to change of raw water demand cannot be detected in time.

line was installed to permit blowoff of reservoir water from the bottom of the stagnation zone, rather than to allow overflow of surface water across the dam.

This simple expedient was extremely effective in reducing the color of the reservoir water. It will be noted that during the summer of 1947, color did not rise above 45 ppm., and since this time there has been a very definite diminution of color.

The lowering of raw water color and the application of high dosages of chlorine enabled the plant to operate about 90 per cent of the time without the use of alum, and to produce a water with 5–10 ppm. of color.

Figure 3 shows chlorine dosages at the Nyack plant. The amounts fed vary, producing a disinfecting dosage of 2 ppm., a break-point dosage of 6–7 ppm. and a free residual chlorination (with dechlorination) dosage of about 8–9 ppm. during the winter months and 12 ppm. in the summer. Maximum dosages are about 18 ppm.

Figure 4 shows the color of raw and treated waters. Alum was required for periods of only about one and one-half months during the years 1949 and 1950, respectively. As at Ossining, alum seemed indicated when raw water color exceeded approximately 40 ppm. The color of the finished water varied from 2–10 ppm., with an average of approximately 5 ppm.

Conclusions

In considering this type of treatment it is necessary to be intellectually honest as well as to accept and be happy with what (at this stage) seem to be the answers. On this basis, therefore, the following conclusions have been drawn:

The taste and odor of the finished water is greatly improved and sporadic outbreaks of the qualities are practically eliminated. The color of the raw water is greatly decreased, although this reduction is not as great as that obtained by conventional coagulation. Plain filtration will not produce the sparkling clarity or "polish" that is possible with good coagulation and filtration, but it will produce a water of satisfactorily low turbidity in the range of 0.3–1.0 ppm.

This process requires machines with a chlorinating capacity of about 140 lb. per mgd., and a dechlorinating capacity of about 40 lb. per mgd. It is also advisable to install a continuous chlorine recorder (at Nyack the sulfur dioxide machine has been automatically controlled by the chlorine recorder for more than a year). This equipment is of course costly, but considering the results obtained, the costs seem fully justified.

The greatly increased cost of chlorine and sulfur dioxide just about offsets the reduction in costs of ammonia, activated carbon, alum, primary alkali (if required) and secondary alkali. If ton containers of chlorine are available (the market is extremely tight at present), chemical costs will show an appreciable decrease.

The operation of the plant is greatly simplified, and, for this reason, at Nyack and Ossining operators would hate to return to the older methods of treatment.

The new type of treatment offers a possibility for far greater economy of plant design than has been practiced in the past. It is confidently predicted, furthermore, that the venturesome engineer of the future who does not mind sticking his neck out to a degree, and who is seriously desirous of producing an adequate treatment plant at very low initial costs, is going to install plants for reservoir waters of low color, consisting only of filters, aerators, chlorinating and dechlorinating apparatus.

The time is not too far distant when someone will approach the water treatment problem from some fresh viewpoint and render obsolete today's conventional methods.

Relative Resistance of Coliform Organisms and Enteric Pathogens in the Disinfection of Water With Chlorine

By Paul W. Kabler

A paper presented on October 17, 1950, at the Southwest Section Meeting, New Orleans, La., by Paul W. Kabler, Senior Surgeon, U.S. Public Health Service, Environmental Health Center, Cincinnati, Ohio.

THE concept of associating water with intestinal ailments evolved long before the bacteriological and medical origins of enteric diseases were known. By the middle of the nineteenth century, Snow and Budd in England had demonstrated epidemiologically that the causative factors of some intestinal diseases were in the water consumed by the sick. In 1880 Eberth described *"Bacterium typhosus"* (*Salmonella typhosa*) and recognized it as the causative agent of typhoid fever. In 1885 Escherich isolated *"Bacterium coli"* (*Escherichia coli*) and *"Bacterium aerogenes"* (*Aerobacter aerogenes*) from fecal materials.

As water bacteriology developed, it was logical that maximum interest should center in the detection and isolation of intestinal pathogens. The difficulties involved in isolating these organisms from water, however, were quickly recognized. Laws and Andrews (1) in 1894 failed to isolate *S. typhosa* from London sewage. Difficulty in isolating these organisms from polluted wells was also encountered by Kübler and Neufeld (2) in 1899 and by Fischer and Flatau (3) in 1901.

Methods for the quantitative isolation of enteric pathogens subsequently improved, and the isolation of *S. typhosa* has been reported by Wilson (4, 5), Wilson and Blair (6), Green and Beard (7), Ruchhoft (8) and others from sewage and polluted waters. Despite the improvement in methods, no medium or procedure for the enumeration of intestinal pathogens has been developed to date which is feasible for use in the average laboratory or is sufficiently sensitive and rapid to be of value in estimating the sanitary quality of water.

The isolation of *Esch. coli* and *Aer. aerogenes* from feces by Escherich, and the subsequent demonstration by a number of investigators of their normal presence in the feces of man and warm-blooded animals, suggested the use of the coliform group as an indicator of the possible presence of enteric pathogens. In 1905 the first committee on standard methods for the examination of water in the United States recommended to the Laboratory Section of the American Public Health Association the use of the coliform group as a criterion of fecal pollution, and the various editions of *Standard Methods* (9) since have specified procedures for the detection of the same group of bacteria, whether referred to as *"B. coli," "Bacillus coli,"* the "colon group," the

"coli-aerogenes group" or the "coliform group."

Relative Resistance

When disinfectants first came into use in the treatment of water supplies, *Esch. coli* was apparently considered more resistant to various chemical agents than the pathogenic intestinal bacteria. Wesbrook, Whittaker and Mohler (10) in 1910 published the first results on the relative resistance of *Esch. coli* and *S. typhosa* to chlorine (calcium hypochlorite). They studied six strains of "*B. typhosus*" and "*B. coli*" which had resided on artificial media for from one to eighteen months, adding varying amounts of hypochlorite solution to a suspension of bacteria in water kept at room temperature. They found that varying amounts of chemicals were required to sterilize different cultures and strains of both colon and typhoid bacilli. In two out of twelve experiments, more hypochlorite was required to produce sterility in the typhosus than in the coliform suspensions. The minimum amount of chemical required for "*B. coli*" in the minimum time tested was from 1.5 to 3+ ppm. of available chlorine, and for "*B. typhosus*," from 1 to 3 ppm. The authors were of the opinion that their results indicated, in a very general way, that "the use of the presence or absence of *B. coli* in a water supply as a guide to the possible presence or absence of typhoid bacilli might be warranted pending the formulation of better technical methods."

Tonney and others (11, 12) in 1928 and 1930 studied the minimal "chlorine death points" of 503 vegetative and spore-bearing strains of bacteria (48 species), among which were 21 strains of *S. typhosa*, 33 of *Esch. coli* and 41 of *Aer. aerogenes*. The authors give no history of the strains examined nor do they indicate the length of time they were grown on artificial media. Using distilled water for preparation, they found that exposure for 15 to 30 seconds to 0.1 ppm. of chlorine was sufficient to kill all the *S. typhosa*; 13 strains of *Esch. coli* exposed for the same time were killed by 0.15 ppm. of chlorine, 10 strains by 0.20 ppm., and 9 strains by 0.25 ppm. The results for *Aer. aerogenes* were similar to those for *Esch. coli*. Thus the investigators concluded: "The experiments appear to furnish a satisfactory theoretical basis for the current practice of relying on the consistent destruction of *Esch. coli* in water as a criterion of effective chlorination"

Chlorine Residual

Griffin (13) in 1934 stated that fully 99 per cent of *Esch. coli* in average waters was killed with relatively small residuals of chlorine, and that, for a given contact time, chloramine residuals two times greater than chlorine residuals would accomplish approximately the same results. He further stated that "higher residuals are required with alkaline waters than with acid waters in order to effect complete elimination of *Esch. coli*."

As part of the investigations following an outbreak of typhoid fever in Minneapolis, the comparative "resistance of various strains of *Eberthella typhosa* and coli-aerogenes to chlorine and chloramine" was studied by Heathman, Pierce and Kabler (14). They used tap water with a pH range of from 6.4 to 7.9 as a suspending medium. Observations were made in two temperature ranges, room temperature and slightly above freezing. Although the chlorine residual tests and the na-

ture of the tap water used make it impossible to state positively whether the available chlorine present was free or combined, it was clearly established that there is a considerable variation in the resistance of freshly isolated strains of *"E. typhosa"* and members of the "coli-aerogenes" group, that considerably longer periods of exposure are required at low temperatures, and that certain strains of *S. typhosa* exhibit as great or greater resistance to chlorine than some strains of the coliform group. In later experiments, Kabler, Pierce and Michaelsen (15) showed that freshly isolated strains of *S. typhosa* exhibit an appreciably greater resistance to combined available chlorine than do strains that have resided on artificial media for indefinite periods of time. They pointed out the possible danger of using old laboratory strains to determine the effectiveness of chlorine as a disinfectant.

Bactericidal Efficiency

Butterfield and his associates (16–19) of the Water and Sanitation Investigation Station at Cincinnati, now the U.S. Public Health Service Environmental Health Center, systematically investigated the various factors influencing the bactericidal action of chlorine in water treatment. In these studies, tests were made using free available chlorine with no trace of combined available chlorine present and combined available chlorine with no free available chlorine present. The tests were made at pH values ranging from 6.5 to 10.7 in two temperature ranges of 2°–5°C. and 20°–25°C. The organisms tested were *Esch. coli, Aer. aerogenes, Pseudomonas aeruginosa, S. typhosa* and several strains of *Shigella* (dysentery) organisms.

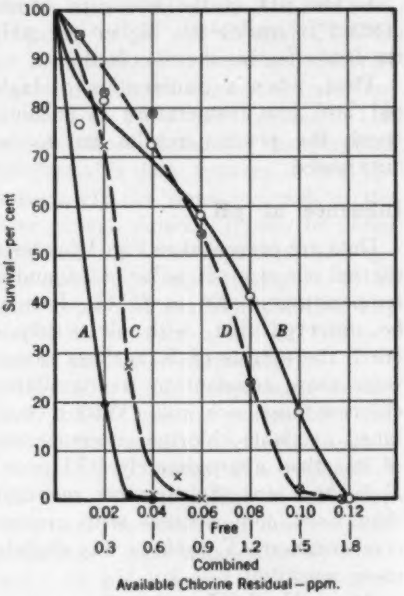


Fig. 1. Action of Available Chlorine Residual on Esch. Coli and S. Typhosa

The tests reported in the diagram above were performed at a pH value of 7.0 and temperatures of 20°–25°C. The curves indicate the effect of available chlorine residual on four species of bacilli. They may be identified as follows:

A—Esch. coli with free available chlorine
B—Esch. coli with combined available chlorine
C—S. typhosa with free available chlorine
D—S. typhosa with combined available chlorine

They found that, in general, the primary factors governing the bactericidal efficiency of both free available chlorine and combined available chlorine were the following:

1. The time of contact of the organisms and the bactericidal agent—the longer the time, the more effective the disinfection.

2. The temperature of the water in which contact is made—the lower the temperature, the less effective the disinfection.

3. The pH of the water in which contact is made—the higher the pH, the less effective the disinfection.

Thus, when a combination of high pH and low temperature is encountered, the poorest results are to be anticipated.

Influence of pH

Data are presented in Fig. 1 for tests carried out at a pH value of 7.0 and a temperature of 20° to 25°C. It may be observed that, with all residuals tried, the strains of *S. typhosa* tested were more resistant to free available chlorine than *Esch. coli.* With a combined available chlorine concentration of less than approximately 0.75 ppm., *S. typhosa* was slightly more resistant than *Esch. coli,* whereas with greater concentrations, *S. typhosa* was slightly more sensitive.

At a pH of 9.5 and a temperature of 20°–25°C. the difference in sensitivity of *Esch. coli* and *S. typhosa* was greatly reduced for both free and combined available chlorine, with practically no variation in the rate of kill being apparent for either (Fig. 2). In summing up all the data about free available chlorine Wattie and Butterfield (17) stated:

1. At pH values of 6.5 and 7.0, typhosa strains were consistently more resistant than coliform strains.

2. At pH 7.8, coliform strains were more resistant with concentrations of free available chlorine exceeding 0.03 ppm.

3. At pH 8.5 and above, all strains of *Esch. coli* tested were consistently as resistant, and usually much more resistant, to free available chlorine than any *S. typhosa* strains. Although the range of probable error did not permit determination of the point between pH 7.0 and 8.5 where a "change-over" in sensitivity occurred, the consistency of the results at pH 6.5 and 7.0 and at pH 8.5 or above left no doubt of the existence of the "change-over."

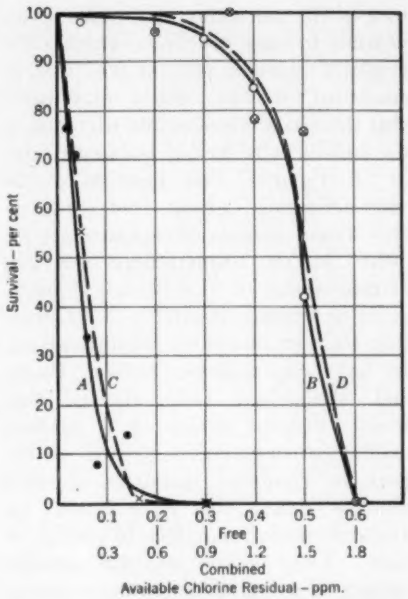


Fig. 2. Action of Available Chlorine Residual on Esch. Coli and S. Typhosa

The tests reported in the diagram above were performed at a pH value of 9.5 at temperatures of 20°–25°C. With this pH, the difference in sensitivity of Esch. coli and S. typhosa was greatly reduced with both free and combined available chlorine, practically no variation in the rate of kill being apparent for either. The curves may be identified as follows:

A—Esch. coli with free available chlorine
B—Esch. coli with combined available chlorine
C—S. typhosa with free available chlorine
D—S. typhosa with combined available chlorine

Only slight differences were observed in the sensitivity of the two genera when combined available chlorine was used as a bactericidal agent. In a few tests *Esch. coli* was more resistant to combined available chlorine

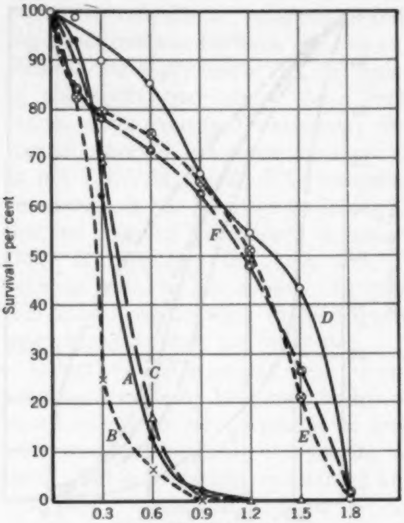


Fig. 3. Effect of Temperature on Action of Combined Available Chlorine

The effect of variations in temperature on the bactericidal efficiency of combined available chlorine is shown in the diagram above. The average results obtained after 60 minutes' exposure in waters with a pH value of 8.5 are plotted against the residual chlorine in parts per million. The curves may be identified as follows:

Genus	Temperature °C.
A—Esch. coli	20°–25°
B—S. typhosa	20°–25°
C—Shigella sonnei	20°–25°
D—Esch. coli	2°–6°
E—S. typhosa	2°–6°
F—Shigella sonnei	2°–6°

than *S. typhosa*, particularly at pH 7.8 and 10.5, but in general they were about equally sensitive.

Temperature

The effect of variations in temperature on the bactericidal efficiency of combined available chlorine is shown in Fig. 3. The average results obtained after 60 minutes' exposure in waters with a pH value of 8.5 at temperatures of 20°–25°C. and 2°–6°C. for *Esch. coli, S. typhosa* and *Shigella sonnei* are plotted against the residual chlorine in parts per million. The marked effect of the 20° temperature differential is quite apparent. It is approximately the same for each of the three genera shown. It may be noted that, with the same exposure time, approximately 2.5 times (range 1–4) as much combined available chlorine was needed to produce a kill of 100 per cent at the lower temperature.

The influence of temperature on the *Esch. coli* kill was not marked in water with a free available chlorine and a pH value of 7, except at a residual of 0.02 ppm. With residuals of 0.03 ppm. and more, the results obtained at each temperature were approximately identical. At pH 9.8 and 10.7, the temperature effect was much more pronounced throughout the range of available chlorine tried; much more chlorine was required during the same time span at a temperature of 2°–5°C. than at a temperature of 20°–25°C. The influence of temperature on the bactericidal efficiency of free available chlorine for *S. typhosa* at pH 7.0 and 9.8 is similar to that for *Esch. coli.* At pH 7.0, temperature apparently has only a slight influence on the toxicity of free available chlorine for *S. typhosa*; whereas at pH 9.8 approximately three times as much free available chlorine is needed to produce the same results at 2°–5°C. as at 20°–25°C.

Genus Sensitivity

The results obtained with five genera at a pH value of 7.0 and a temperature range of 20°–25°C. are shown in Fig. 4. The most resistant was *Aer. aerogenes* with *S. typhosa, Shigella dysenteriae, Esch. coli* and *Ps. aeruginosa,*

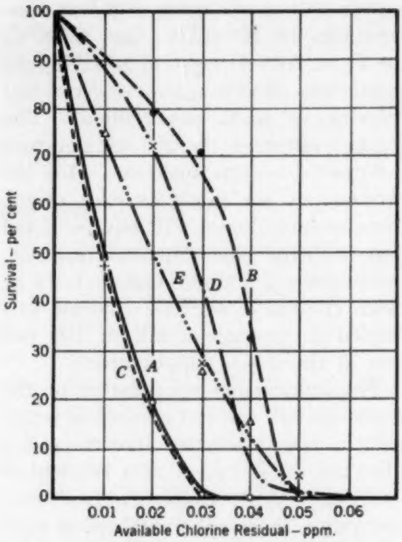


Fig. 4. Sensitivity of Five Genera of Bacteria to Chlorine Treatment

The results obtained with five genera at a pH value of 7.0 and a temperature range of 20°–25°C. are shown in the diagram above. The curves may be identified as follows:

A—Esch. coli (2 strains)
B—Aer. aerogenes (2 strains)
C—Ps. aeruginosa (2 strains)
D—E. typhosa (2 strains)
E—Shigella dysenterie (3 strains)

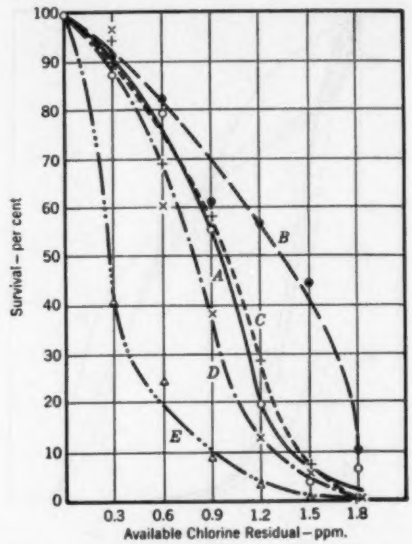


Fig. 5. Resistance of Five Genera of Bacteria to Combined Available Chlorine

The average percentage of survival of the various genera are plotted against the residual chlorine in parts per million. A pH value of 7.8 and temperatures of 20°–25°C. were used. The curves may be identified as follows:

A—Esch. coli
B—Aer. aerogenes
C—Ps. aeruginosa
D—S. typhosa
E—Shigella dysenteriae

following in order. It may be noted that about 0.03 ppm. more free available chlorine was required to obtain the same percentage of kill of the most resistant species as of the most sensitive species. At pH values of 8.5 and above and temperatures of 20°–25°C., *S. typhosa* was found to be most sensitive to the effects of the chlorine, *Esch. coli* rated next and *Ps. aeruginosa* proved to be the most resistant. When the two temperature ranges—2°–5°C. and 20°–25°C.—were compared at pH 7, *S. typhosa* and *Esch. coli* proved to be about equally sensitive. At pH 9.8, however, *Esch. coli* was definitely more resistant to free available chlorine than *S. typhosa.*

The variations in the resistance of five genera to combined available chlorine at pH 7.8 and 20°–25°C. are shown in Fig. 5. The average percentage of survival of the various genera are plotted against the residual chlorine in parts per million. Of the five genera dealt with, *Aer. aerogenes* strains were the most resistant and the *Shigella dysenteriae* the least resistant. *Esch. coli, Ps. aeruginosa* and *S. ty-*

phosa showed similar sensitivities falling about midway between the two extremes. At a pH above 7.8, the order of sensitivity may show some variations with increased residuals; the trends, however, are about the same as at pH 7.8. At the 2°–5°C. temperature range, it has been shown in Fig. 3 that no marked differences in sensitivity are apparent for *Esch. coli, S. typhosa* and *Shigella sonnei*. In general *Esch. coli* appears to be slightly more resistant than the other two.

Butterfield (20) summarized the observations made by his group and proposed minimum safe residuals of free and combined available chlorine to be used. These proposals represented liberal safety factors in addition to the observed amounts of chlorine required under various combinations of pH and temperature.

Conclusions

1. Observations on the relative survival of the species studied under varying conditions of pH and temperature show that at pH values of 7.8 and less, with free available chlorine concentrations of 0.03 ppm. or less, *S. typhosa* was slightly more resistant than *Esch. coli* or *Ps. aeruginosa*. At all other concentrations of chlorine at pH of 7.8 or less and at pH values of 8.5 or greater the reverse was true.

2. Under certain conditions, when combined available chlorine was used as a bactericidal agent, some strains of *S. typhosa* and *Shigella sonnei* appeared to be slightly more resistant than some strains of *Esch. coli*. They were not, however, found any more resistant than strains of *Aer. aerogenes* studied.

3. Combined available chlorine is much less efficient as a bactericidal agent than free available chlorine. To obtain a kill of 100 per cent with the same period of exposure, about 25 times as much combined available chlorine as free available chlorine was required. To obtain the same kill with the same amounts of free and combined available chlorine under the same conditions required approximately 100 times the exposure period for the combined available chlorine.

4. The proposed minimum safe chlorine residuals are about twice the average amount required to kill the bacterial species examined and are under all conditions of test appreciably greater than the amount of available chlorine required to kill the most resistant species. They allow a liberal safety factor to cover varying conditions of plant operation and the training and experience of the plant operator.

5. After evaluation of the available data it appears that the coliform group can be considered safe indicators for adequate treatment of bacterial content. Whether this consideration can be expanded to cover rickettsial and viral organisms that may be found in water is yet to be established.

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Effect of Stepwise Chlorination on Taste- and Odor-Producing Intensity of Some Phenolic Compounds

By M. B. Ettinger and C. C. Ruchhoft

A contribution to the Journal by M. B. Ettinger, Scientist, and C. C. Ruchhoft, Sanitary Engineer Director, U.S. Public Health Service, Environmental Health Center, Cincinnati, Ohio.

An extended series of investigations of the quality and intensity of the tastes produced by chlorination of various phenolic materials was reported by Adams (1) in 1931. In the light of present knowledge, the importance of the precise values reported must be regarded as secondary, as there was no mention of the exact conditions of chlorination. Adams' summation of experimentally observed variations in group and individual sensory perceptions of tastes and odors produced by chlorinated phenolic materials, however, is sufficiently fundamental to deserve repetition at this time:

> Generally, women and children are far more sensitive to this taste than are men. The former are usually able to detect from one-fifth to one-tenth the minimum quantity observed by the latter. That the gustatory nerves are more sensitive toward this particular taste and hence that the taste limit is far below the odor limit has also been shown. About one-hundredth of the quantity detected by odor can be detected by taste.

Discussing factors which affected his tests, Adams stated:

> the difficulties in taste experiments of this nature are considerable and may be thus summarized: (a) The practical impossibility of working in an average ordinary chemical laboratory owing to absorption of miscellaneous fumes and odors, (b) variability of tongues and palates, (c) influence of light, (d) occurrence of taste-producing substances "normally" present in the control sample, (e) the chlorine dose, which in some cases may be a super dose, but an under dose in others and (f) period of contact—some tastes disappearing on standing whereas others develop slowly.

That a definite relationship affecting taste intensity exists between the chlorine dose and the phenol content is pointed out by Howard (2), and data presented in this paper are in complete agreement with that principle. Failure to make allowances for the operation of this variable limits the value of Adams' observations.

For the results to have any meaning, a procedure for measuring the sensory effects of chlorinated phenolic materials should satisfy these requirements:

1. The conditions of chlorination should be rigidly standardized and should include a sufficient variation in the ratio of chlorine added to the amount of phenolic material present to allow the production of a mixture which will give the maximum sensory effect.

2. The sensory perception of the observer should be conserved as much as possible. Increasing concentrations of the material should be examined until the threshold of perception is determined, in order to avoid saturating the observer's olfactory or gustatory perception. Sufficient time should elapse following positive observation before subsequent examinations are conducted.

3. The observer must not know the concentration of the material he is examining. Thus, the observation reported will be a purely sensory observation less subject to error caused by suggestion.

Procedure

The procedure for studying the effect of variable controlled chlorination on the taste of phenolic materials is detailed below.

1. *Stock Solutions*

An aqueous 1,000-ppm. solution of the phenolic material under investigation must be prepared, using chlorine-free and chlorine-demand–free water.* A small amount of NaOH may be added if necessary. If the solution is unstable (that is, 1-naphthol), it must be freshly prepared. If a solution of 1,000-ppm. concentration cannot be prepared because of the low solubility of the compound, a 100- or a 10-ppm. solution (highly chlorinated phenols) may be prepared.

2. *Procedure*

A. *Solution for chlorination*

A 1-ppm. solution of the phenolic material under investigation is prepared by adding the stock solution to newly prepared chlorine-demand–free distilled water in the indicated amount. Sufficient 10 per cent $NaHCO_3$ solution is then added to give 100 ppm. of $NaHCO_3$.

B. *Chlorination*

Using 500-ml. portions of the solution prepared, a series of portions containing increasing amounts of chlorine are prepared. In general, a satisfactory series comprises the following chlorination steps: 0, 0.5, 1, 1.5, 2, 3, 4, 5, 6, 7, 8, 9 and 10 ppm. of chlorine. The chlorine solution may be added in the form of a standardized chlorine water solution or a chlorine water solution with just sufficient NaOH added to remove the green color. This latter type of solution is designated as "hypochlorite" in the discussion, and it has been used at times to increase the stability of chlorine solutions.

The solutions are allowed to stand in the light, but not where they will not be exposed to direct sunlight or strong illumination. After two hours, the pH is determined (electrometrically) and the *p*-aminodimethylaniline flash test (4) is made. If the pH is unsatisfactory (below 7.0), a new series is set up, using more bicarbonate buffer. If several portions do not react positively in the flash test, additional units are added to the series using more chlorine; this condition is rarely encountered, however.

After 18–24 hours the pH, the *p*-aminodimethylaniline flash test and the total residual chlorine by normal orthotolidine procedure (5) are determined. If there are no positive flash tests, a breakpoint series has not been obtained. Before tasting, samples showing residual chlorine by the orthotolidine test are dechlorinated by the addition of small amounts of 1 per cent sodium sulfite solution. The addition of too much sodium sulfite may be avoided by adding it in small increments; the solution should be mixed

* The stipulation "chlorine-demand–free water" entails that the water also be ammonia-free.

by shaking after each increment and then tested for residual chlorine with orthotolidine reagent on a spot plate. A small quantity of the reagent is also added after the spot plate test becomes negative.

The approximate taste threshold is estimated from test samples on the basis of odor observations and cut-and-try tests on increasingly concentrated dilutions of the chlorinated subsample. With two men working as a team, a series of dilutions of the chlorinated subsample in "odor-free" water is then prepared. The series should be designed to give some positive and some negative taste tests. The observer must taste the series of diluted samples without knowing the concentration he is tasting. Blanks are inserted in the series to insure that each portion is impartially examined. The more diluted portions are tasted first so that the observer's sense of taste will not be impaired by grossly flavored solutions. When the observer has encountered the first positive taste test the observation is carried one or two steps further until unmistakable tastes are encountered. A typical test series might proceed as follows, assuming a threshold of 400:

Dilution or Blank	$\frac{1}{100}$	$\frac{1}{200}$	*B*	$\frac{1}{400}$	*B*	$\frac{1}{800}$	$\frac{1}{1600}$
Order of Tasting	7	6	5	4	3	2	1
Observer's Reaction	++	+	−	±	−	−	−

All samples not showing a positive *p*-aminodimethylaniline flash test are tasted, as are a sufficient number of samples showing free chlorine to indicate the pattern of the tastes remaining after free residual chlorination.

TABLE 1

Effects of Stepwise Chlorination of 1 ppm. Phenol on Taste Intensity

Chlorine Added *ppm.*	2-hour Observations		24-hour Observations			
	pH	Flash*	pH	Flash*	Residual (o-t.)	Dilutions to Threshold
0	7.8	−	8.0	−	0.00	0
0.5	7.9	−	8.2	−	0.00	100
1	8.1	−	8.2	−	0.00	200
1.5	8.2	−	8.3	−	0.00	200
2	8.3	−	8.3	−	0.00	400
3	8.2	−	8.2	−	0.00	100
4	8.1	−	8.2	−	0.00	0
5	7.9	−	7.9	−	0.00	0
6	7.8	+	7.9	−	trace	1
8	7.8	+	7.9	+	0.24	0
10	7.6	+	7.9	+	0.90	0

* *p*-Aminodimethylaniline flash test.

Step Chlorination

All of the taste studies reported in this paper represent the sensory reactions of one observer. The data presented are therefore comparative in terms of a given observer and subject to variations in the sensory acuteness of that observer. The observer was a male with a consistent but not hypersensitive sense of taste. It would appear likely, therefore, that a very considerable number of people might be

able to detect much smaller portions than the minimum amount reported by this observer.

The data presented are based on chlorination reactions carried out in the presence of diffused sunlight of variable intensity during the first seven or eight hours of chlorination. Exposure to direct sunlight was avoided.

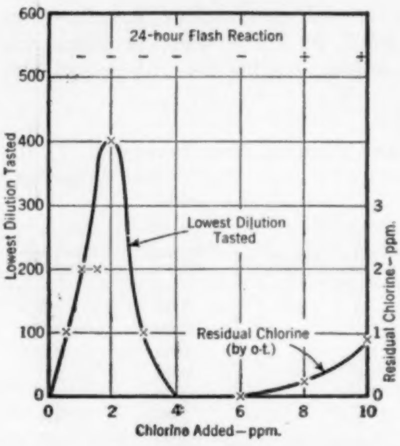

Fig. 1. Effect of Stepwise Chlorination on the Taste Intensity of 1 ppm. of Phenol

From bench results of a stepwise chlorination of phenol it may be seen that the effect of the chlorination is, first, to increase the taste intensity of the solution enormously. When a maximum taste intensity has been reached, further chlorination results in a progressive decrease in taste until the solution no longer has a detectable taste.

The pH of the reaction mixtures was found to vary between 7.0 and 8.4. Because of this variation, the data may not be strictly reproducible, and there is a possibility that different results might be obtained at other pH values or with different exposures to light.

The source of the phenol, the cresols and the 1-naphthol used has been described (6). The chlorinated phenols used were laboratory-purified chemicals supplied through the courtesy of the Dow Chemical Co.

The bench results from a stepwise chlorination of phenol are presented in Table 1 and these data are graphically presented in Fig. 1. A similar set of results for para-cresol are given in Table 2 and presented graphically in Fig. 2. It may be seen that the effect of the chlorine is, first, to increase enormously the taste intensity of the solution. When a maximum taste intensity has been reached, further chlorination results in a progressive decrease in taste until the solution no longer has a taste detectable by the observer.

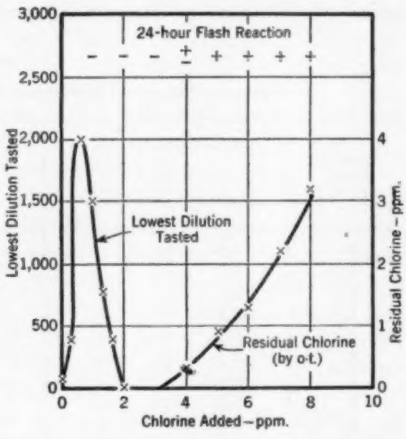

Fig. 2. Effect of Stepwise Chlorination on the Taste Intensity of 1 ppm. of Paracresol

The bench results of a study of stepwise chlorination of p-cresol show that small differences in the amount of chlorine added have a great effect on the taste intensity of the solution.

The chlorinated phenols which result from the usual reactions of chlorine with phenol, and the 2-, 3-, 4-, and 6-tetrachlorophenol and pentachloro-

TABLE 2

Effects of Stepwise Chlorination of 1 ppm. Para-cresol on Taste Intensity

Chlorine Added *ppm.*	2-hour Observations		24-hour Observations			
	pH	Flash*	pH	Flash*	Residual (o-t.)	Dilutions to Threshold
0	7.0	–	7.1	–		50
⅓	7.0	–	7.1	–		400
⅔	7.0	–	7.1	–		2,000
1	7.0	–	7.1	–		1,500
1⅓	7.0	–	7.1	–		800
1⅔	7.0	–	7.1	–		400
2	7.0	+	7.1	–		2
3	7.0	+	7.2	–		0
4	7.0	+	7.1	±	0.34	0
5	7.0	+	7.1	+	0.92	0
6	7.0	+	7.2	+	1.3	0
7	7.0	+	7.1	+	2.2	0
8	7.0	+	7.1	+	3.2	0

* *p*-Aminodimethylaniline flash test.

phenol have been studied by the procedures outlined. The principal features of this material are reported in Table 3. It will be noted that some of the chlorophenols studied could not be tasted in 1-ppm. concentrations, or in any solution prepared by the chlorination of a 1-ppm. concentration. For those chlorophenols which had a detectable taste, Fig. 3 shows the variation of the taste intensity as a function of the amount of chlorine added.

It is interesting to note that among the chlorophenols studied, only 2-chlorophenol had an especially intense taste. It will be further observed that

TABLE 3

*Stepwise Free Residual Chlorination Studies of Some Phenolic Materials**

Material	Dilution to Threshold, Unchlorinated	Chlorine at Maximum Taste *ppm.*	Dilution to Threshold at Taste Maximum	Chlorine Added to Produce Free Residual *ppm.*	Chlorine Required to Eliminate Taste *ppm.*
Phenol	0†	2	400	7	4
o-Cresol	10	2	800	5	5
m-Cresol	4	1	1000	5	5
p-Cresol	50	⅔	2000	4	3
1-Naphthol	30	0	30	5	4
2-Chlorophenol	100	½	400	5	3
4-Chlorophenol	2	1	8	6	3
2-, 4-Dichlorophenol	4	0	4	6	2
2-, 4-, 6-Trichlorophenol	0†	–	0	3	–
2-, 4-, 5-Trichlorophenol	0†	–	0	2	–
2-, 3-, 4-, 6-Tetrachlorophenol	0†	–	0	1.5	–
Pentachlorophenol	0†	–	0	1.0	–

* Contact time, 24 hours; 1 ppm. solutions studied.
† Could not be tasted by observer.

2-chlorophenol increases in taste intensity as a result of partial chlorination.

The chlorophenols studied include all the chlorinated phenol compounds which might reasonably be expected to result in appreciable quantity from the chlorination of phenol. Thus, it seems highly improbable that any of the usual chlorinated phenols are responsible for the "chlor phenol" taste. This conclusion is emphasized by the fact that *o*-chlorophenol, considered by Adams (1) to be the cause of "chlor phenol" taste, undergoes a very considerable increase in the intensity of its taste as the result of partial chlorination.

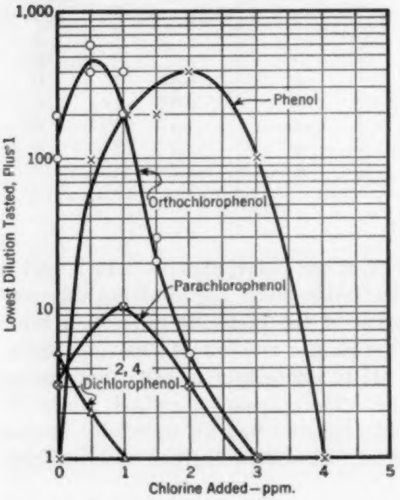

Fig. 3. Effect of Stepwise Chlorination on the Taste Intensity of 1 ppm. of Phenol and Some Chlorophenols

The variation of the taste intensity of those chlorophenols which had a taste is shown as a function of the amount of chlorine added.

While the data furnish a good deal of evidence concerning materials which are not the cause of the "chlor phenol" taste, there is nothing to indicate the exact nature of the material of the reactions causing these tastes and odors.

The bench results of a study of stepwise chlorination of *p*-cresol are given in Table 2 and graphically presented in Fig. 2. These data are of particular interest because they demonstrate that small differences in the amount of chlorine added had an enormous effect on the taste intensity of the solution.

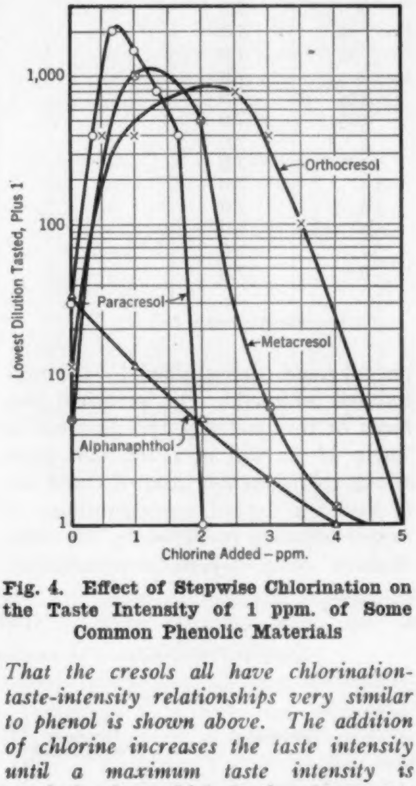

Fig. 4. Effect of Stepwise Chlorination on the Taste Intensity of 1 ppm. of Some Common Phenolic Materials

That the cresols all have chlorination-taste-intensity relationships very similar to phenol is shown above. The addition of chlorine increases the taste intensity until a maximum taste intensity is reached, after which further increments of chlorine result in a progressive decrease of taste until it is no longer detectable.

Table 3 presents the principal features of stepwise free residual chlorination studies of the three cresols and

l-naphthol along with similar data for phenol and various chlorinated phenols. The effect of variable additions of chlorine on the taste intensity of the cresols and l-naphthol is shown graphically in Fig. 4.

That the cresols all have chlorination-taste intensity relationships very similar to phenol is shown in Fig. 4; the addition of chlorine increases the taste intensity until a maximum is reached, after which further increments of chlorine result in a progressive decrease of taste level until it is no longer detectable.

With l-naphthol, on the other hand, chlorination does not cause an increase in taste intensity, a decrease in taste being noted at all times as chlorine is added.

Conclusions

1. The phenolic materials studied fall into three principal groups, as determined by the results of stepwise partial chlorination of 1-ppm. concentrations:

a. Phenolic materials which have their taste-producing intensity enormously increased by partial chlorination until a maximum taste intensity is reached, after which further addition of chlorine results in a progressive decrease of the taste intensity until the "chlor phenol" taste can no longer be detected. This group of materials includes phenol, the cresols and *o*-chlorophenol.

b. Phenolic materials which have their taste intensity progressively decreased by chlorination. This group includes l-naphthol and 2-, 4-dichlorophenol, among the limited number of compounds studied.

c. Phenolic materials of limited intensity as taste-producing substances in small concentrations. This group includes 4-chlorophenol and all the phenols studied which had three or more positions chlorine substituted.

The taste of the 4-chlorophenol compound was enhanced slightly by chlorination, but never reached a high intensity, whereas the other materials mentioned were never detectable by the observer.

2. Chlorination beyond the breakpoint, with sufficient time allowed for reaction, resulted in substantially no "chlor phenol" tastes. The indication is that true free residual chlorination, in which all reactions which consume free chlorine have been allowed to occur, will eliminate the "chlor phenol" tastes caused by the compounds studied. A system must show a truly stable free chlorine content, however, as shown by either electrometric evidence or the *p*-aminodimethylaniline flash test. In various partially chlorinated systems, which show a positive reaction to orthotolidine or starch-iodide tests but do not actually contain a real stable free chlorine residual, the "chlor phenol" medicinal tastes occur.

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Ecology of Significant Organisms in Surface Water Supplies

By C. M. Tarzwell and C. M. Palmer

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IT is recognized that the preparation of water for urban consumption should free it of all materials which might make it harmful to health or which might limit its use by householders and by industries. Although whether or not the water should be freed of all chemicals may be controversial, it is agreed that water should not contain microorganisms. Disease-producing forms must be eliminated, as well as those causing turbidity, unsightliness, tastes and odors.

Other microorganisms, if present in water, cause trouble when the product is used in such enterprises as paper manufacture and the dairy industry. These organisms can also cause trouble in the water works by clogging filters and water lines or by multiplying in storage basins, even after the water has been purified and is otherwise ready for use.

Scope of Problem

It must be emphasized that, although in the final purification of water for urban use the algae and other microorganisms should be eliminated or reduced to a minimum, it is often neither practical nor desirable to carry this out in the streams and reservoirs. The preliminary handling of the water in these streams and reservoirs calls for practices which will control the number and kinds of organisms in a manner that will preclude such troubles as blooms, tastes and odors and clogging of the filters at the purification plant.

Chemical control requires periodic applications which may be harmful to other forms of life. It is also very costly in large bodies of water, or where treatment is required over considerable periods. This type of control is furthermore economically unfeasible in large streams when only a fraction of the total flow is used. Known methods of chemical control are also ineffective for some types of organisms. For effective control, it may be necessary to combine biological and chemical methods and to neutralize or adsorb offending substances at the water plant.

The control of tastes and odors has become an outstanding problem to water plant operators. The depletion of ground water supplies and increases in population, with greater domestic and industrial demands, are making it necessary for more and more municipalities to turn to surface water supplies. Because ground waters are usually quite free of living organisms, this change in the source of supply greatly extends the problem. Surface waters

support populations of organisms of which some may be responsible for the production of tastes and odors in water supplies.

For those communities which take their supplies from muddy streams, the widespread impoundment program may create problems where none existed before. This dilemma may arise because the removal of silt in the reservoirs allows greater light penetration which in turn promotes algal growths. Storage reservoirs also often produce blooms of taste- and odor-producing organisms.

A variety of factors influence the biological productivity of reservoirs. A lake or reservoir is biologically productive in direct proportion to the fertility of the land which forms its basin and the surrounding watershed, and to the amount of fertilization applied to the soil of the watershed, or arising from domestic or organic pollution. Temperature, sunlight, turbidity, character and amount of rainfall, shape and depth of basin, type and extent of flats, mode of operation, amount of return irrigation water, wind action and the amount of evaporation with the resulting concentration of salts, all influence biological productivity.

Physiological studies and a knowledge of the ecology, life history and the requirements of the various species of taste- and odor-producing organisms are of importance in providing a suitable water supply. Such studies are basic requisites for biological control that is the cheapest and most effective method, when adequate methods can be developed.

Classes of Microorganisms

Microorganisms in water include the protozoa and other small animal forms —collectively known as zooplankton— and the bacteria, actinomycetes, molds and algae—collectively known as the phytoplankton if they are unattached.

The importance of the algae in particular should be emphasized. Algae contain yellow and green, and often blue, red and brown pigments. They vary greatly in size: the smallest are approximately the size of bacteria; the larger forms are easily visible without magnification.

The major groups of algae include the diatoms, desmids, blue-greens, sedentary greens and the pigmented flagellates. Their genera and species number in the hundreds and even in the thousands. It is probable, however, that a relatively small number will be found to be of particular importance to those interested in water purification.

Diatoms, for example, were found to comprise 98 per cent of the total spring crop of algae in western Lake Erie, with one genus, *Asterionella,* being predominant. In the late summer and autumn, greens and blue-greens often constitute more than 50 per cent of the crop, with *Oscillatoria* and *Aphanizomenon* predominating. The algae on the river beds of highly calcareous streams in England constitute a single community throughout the year, dominated by *Cocconeis, Ulvella* and *Chamaesiphon.*

It will eventually be possible to recognize all of the dominant forms of algae. The other forms will be of importance only if they are known to be indicators of a significant change in the algal population which would require special treatment of the water.

Importance of Algae

Algae are probably less troublesome than silt in clogging filters in purification plants, but both algae and bacteria

are significant producers of slime in water and many of the organisms causing odor and taste in water are algae.

Algae seldom cause illness to humans, but they have been responsible for the extensive killing of fish, and in causing illness or death to cattle. They may also be responsible for imparting some toxicity to fish and shellfish.

On the other hand, their liberation of oxygen into the water greatly stimulates the self-purification of streams. Algae are also a basic constituent in the food chain for fish life.

The ability of algae to utilize carbon dioxide is significant to the water plant engineer. In order to prevent corrosion or precipitation of calcium carbonate, the engineer attempts to maintain a calcium carbonate solubility equilibrium in the water. The carbon dioxide content of the water affects this equilibrium.

Classifying Algae

The algae are generally put into two groups, according to their location in the water. The forms which attach themselves to the bottom and sides of the body of water are called "phytobenthon," while the unattached forms which float or are dispersed throughout the water are called "phytoplankton." There is an obvious relationship between the algae of the two groups. Storms and other disturbances release some of the attached, benthonic forms, causing them to become part of the plankton.

It has been found, for example, that *Scenedesmus obliquus, Navicula viridula* and *Cocconeis* are common river-bed forms which also occur in quantity in the plankton. The shallower the river, the larger is the area of river bed exposed to sufficient light to support growth of green plants, and, therefore, the larger the number of sessile algae able to act as a source of supply for plankton.

Water from deep wells is practically free of all organisms, so that if such sources could be used exclusively, many water treatment problems would become comparatively simple. It is, however, becoming increasingly necessary to rely upon surface waters of streams, rivers, lakes and impoundments, in which algae and the other microorganisms are invariably present.

Impoundment Projects

During the past twenty years, there has been a great increase in the number of impoundments. Dams have been built on all major streams for the impoundment and storage of water for a variety of uses. The Tennessee Valley Authority is an outstanding example of the unified development of a river system. The great success obtained in the Tennessee Valley is due largely to the multiple use program and has encouraged similar programs on other watersheds. Programs are now under way, or are being formulated, for extensive water control activities on the most important streams.

These extensive impoundments will have far-reaching beneficial effects, but they may also create problems, especially through their influence on domestic water supplies. Water works supervisors charged with the provision of potable water supplies are apprehensive of the effects of such impoundment on the streams from which they obtain their supplies. Past experience has shown that algae and other growths in some impoundments produce tastes and odors which are difficult to control or remove.

Another pressing problem facing those people who are engaged in the provision of suitable drinking water

supplies is how a dam, or a series of dams, will affect the potability of the waters of a stream. There is currently little definite information which can be applied to predict the effects of a given impoundment, or series of impoundments, on public water supplies that are drawn from surface waters. It is apparent that this question should be given immediate consideration and extensive investigation. That it is a complicated one is indicated by the findings from biological studies and investigations that have been undertaken on impoundments in various parts of the country.

In these impounded waters, the algae may become so abundant that they are readily visible to the naked eye as colored masses of pond scum, but much smaller concentrations can still be significant. A quart of water showing no signs of algae to the naked eye will often contain a population sufficient to clog the sand in a Sedgwick-Rafter filter.

Control of Algae

The common practice for controlling such growths is to treat the water with copper sulfate. Algae vary greatly in their resistance to this chemical, and some groups require applications many times stronger than the amount necessary to control the more sensitive species. The range in sensitivity is approximately 1–100. In some situations chemical treatment is very difficult, and it is usually costly. Copper sulfate is also not effective in controlling some taste- and odor-producing organisms. An alternative that may be desirable, therefore, is biological control by manipulation of the environment. Such control, however, is dependent upon a thorough knowledge of the ecological requirements and life history of the organisms which are to be controlled. Often chemical and biological control may be combined.

The phytoplankton in streams, lakes and impoundments vary greatly in quantity throughout the year. There are so many kinds, and so many physical and chemical factors which affect their growth, that a thorough knowledge of the algae and the water source concerned is essential to control the organisms. Pennak (1) found diatoms becoming abundant at different months of the year in different lakes in Colorado. In Beasley Lake they were abundant in January; in Gaynor Lake, April and May; in Allens Lake, June and July; and in Baseline Lake in November.

Often the attempt to control the phytoplankton is made after they have reached the purification plant in large numbers. Like any other epidemic, the best time to control it is before it has had a chance to become serious.

Dead algae can clog filters as readily as living ones, and tastes and odors cannot always be controlled by merely killing the responsible organisms after they have reached the purification plant. It is necessary to know where the seeding areas for each alga are located and what combinations of factors will stimulate and what ones will retard the growth of the unwanted algae.

The end products produced in sewage decomposition serve, in general, as stimulants for algae, but also many algae are retarded in their spread by streams containing such materials. Some algae will grow better in streams with raw sewage; others are stimulated by sewage products; still others require a stream relatively free of both sewage and its products.

Natural Control Factors

Algal growth is regulated by many chemical and physical factors of the

water, such as pH, silica content, nitrates, carbonates, oxygen, phosphates, temperature, turbidity and water current. Hupp (2), for example, found that soluble silicates in the White River in Indiana decreased before increases occurred in diatom populations, but there was no correlation with other types of algae. He found that decreasing amounts of phosphates corresponded with an increase in phytoplankton as the water moved downstream, indicating that the algae probably utilized the soluble phosphates in their metabolism. Nitrite and nitrate content of the water also decreased previous to plankton pulses. He noted that, as water entered a canal, it contained only a trace of ammonia while algae were numerous. But as the water traveled through the canal, which received no outside pollution, the ammonia increased while the algae decreased. The increase in ammonia may have come from the decaying algal cells.

It was noted in England that increased quantity of the benthonic alga, *Cladophora glomerata,* occurred during May and June as a result of large quantities of sewage in the river. Algae on river beds are observed to be more numerous where the current is fast, and the algae in the side pools connected with rivers are generally very different from those in the river itself.

In the Great Lakes, turbidity caused by lake turnovers in the spring and fall, and by storms and winds between periods of turnover, appears to exert a very important influence on seasonal growth and pulses of algae. Utilization of nutrients by phytoplankton is often controlled by turbidity.

Many other examples might be cited to show how closely the growth of algae is associated with conditions in the stream or lake. Effective control of algae therefore requires information on the chemical and physical condition of the water. Some water laboratories are already making it a part of their routine work to collect such information, but are finding it difficult to use the data in actual control of the algae. Much of the information at present is too general, and there are too many conflicting statements on the effect of environment on algae.

Actinomycetes

Although much remains to be learned concerning the ecology and life history of algae and the basic causes of water blooms, even less is known of the actinomycetes, a group which may be of considerable importance in the production of tastes and odors, particularly in the Southwest. Very little is known of the members of this group which are found in lakes or reservoirs (3).

Studies are needed to determine the organisms responsible for tastes and odors, their ecological requirements and life history, the offensive byproducts which they produce, when they are produced, their durability and their chemical nature. This group may become of particular importance in impoundments where fluctuating water levels create conditions differing from those found in natural lakes. It may be that some of the soil actinomycetes can adapt themselves to life within the fluctuation zone of these impoundments and produce problems that are not encountered in lakes.

Soil and Water Richness

The problems of blooms and of tastes and odors produced by algae, actinomycetes or other organisms can be reduced to a consideration of the

richness of the water and soil, and the rate of utilization of this richness. Many factors influence or determine the biological productivity of reservoirs. The type of area flooded is of importance, especially in small reservoirs or in those having a storage capacity which is large in relation to the total or constant flow.

If peat bogs, mucky areas or marshes are flooded, a great deal of organic material is available and is constantly supplied to the reservoir areas for the production of algal blooms. If such an excess of organic material is available and stratification occurs, anaerobic decomposition takes place to produce foul odors, undesirable tastes and acid conditions. From the standpoint of water supply and wild life, these anaerobic and acid conditions are undesirable. When possible, it would be well to burn such areas in order to remove organic material as well as to produce an ash that would be chemically basic.

Reservoir Clearance

Reservoir clearance is also important. Clearing timber from the total reservoir area and removing or burning all vegetation in the zone of fluctuation is of value for several reasons. This clearance removes a large amount of organic material and thus helps to reduce the initial peak of richness in a new reservoir. At the same time, it permits seining as a commercial fishing operation, improves navigation and conditions for boating in general, and is essential for the operation of a malaria control program.

Reservoirs in areas having rich soils are much more productive than those in areas having poor soils. In limestone regions, and in those areas where the total alkalinity of the water is high, biological productivity is much greater than in areas of granitic, sandstone or igneous rock formations.

Land Use

Land use is another factor to be considered. Reservoirs located in rich farming areas often have extensive algal growths and may have large algal blooms. Fertilization for field crops results in the addition of considerable amounts of materials, nitrates and phosphates, which are essential for the production of aquatic populations.

This situation is well demonstrated in the lower TVA reservoirs where the phosphates are in general the chief limiting chemical factor in phytoplankton production. Nitrates may be present in abundance, but they cannot be fully utilized unless phosphates are present. The TVA storage reservoirs are located in the mountainous areas of the upper valley and receive drainage from areas which are, in part, of igneous origin and are not nearly as rich as the lower or run-of-the-river reservoirs. In Norris Reservoir, free or available phosphates are found in the upper portion near the entrance of tributary streams, but they are used up before the lower portion of the reservoir is reached. In the lower run-of-the-river reservoirs, where the valley is wider and cotton is cultivated, with attendant heavy fertilization, considerable amounts of phosphates are leached from the soil and added to the reservoir. Productivity in these reservoirs is greater than in the storage reservoirs and is indicated by larger fish populations and more rapid growth.

The effects of surface drainage from rich farm lands are indicated by the immense algal blooms which occur in the small lakes and impoundments of Iowa. Algal blooms in these lakes are usually annual occurrences. The algae

are produced in such quantities that they actually form windrows on the shores of the lakes.

The effectiveness of fertilizer in the production of plankton blooms is well illustrated by the use of fertilizer in farm fish ponds for the artificial production of plankton populations. These growths are of sufficient density to reduce light penetration so that rooted aquatics cannot grow.

Erosion

In addition to dissolved nutrient substances, there are other watershed characteristics which affect biological productivity. Erosion on the watershed is of outstanding importance. If the watershed has been severely eroded, a great deal of nonproductive sand and silt is added to the reservoirs. These materials tend to limit production of bottom organisms by a smothering action, and add very little fertility to the water because the enriching materials have already been leached out. Soil erosion also influences productivity in reservoirs by the creation of turbidity which limits light penetration and the growth of phytoplankton.

If reservoirs are built in areas in which erosion has not been extensive previously, but in which it is increasing, however, much rich topsoil is removed and deposited in the reservoir to increase the richness of the bottom areas. During the period of drawdown, these rich silt flats are covered with dense growths of annual plants which, after flooding, add greatly to the richness of the reservoir, and may provide favorable conditions for growth of actinomycetes.

The deposition of rich soil is an annual occurrence that will maintain the productivity of a reservoir over long periods. A classic example of this is the enriching of the Nile Valley, which serves as a temporary reservoir during the annual overflow of the Nile River.

Inflow and Discharge Rates

The relation of the rate of inflow and discharge to the storage capacity of a reservoir is also of importance in determining its biological productivity. Those reservoirs having a large storage capacity relative to their inflow generally have an initial period of great productivity. Furthermore, because the water is stored over considerable periods, there is an opportunity for the silt to settle and the resultant clearing of the water and deeper light penetration encourage greater production of phytoplankton.

In reservoirs of this type, especially if they are in narrow valleys, stratification of the water often occurs in the summer months, causing oxygen depletion and producing anaerobic conditions. If water levels are kept fairly constant and releases are small, there will be regular spring and fall turnovers, resulting in the production of the usual peaks of plankton.

Density currents will probably be produced in such reservoirs, and the level from which water supplies are drawn will influence the character of the water considerably. Intake towers should therefore be so constructed that water can be taken from any desired level.

Reservoir Shape and Depth

The shape of the reservoirs is also instrumental in determining their biological productivity. Narrow, deep reservoirs having a minimum of shore line are generally not as productive over long periods as wide, shallow ones hav-

ing extensive flats, or large flat areas which are exposed by periodic drawdowns.

Operational Schedules

The schedule of operation of an impoundment influences its productivity. Time of impoundment is also of importance. Reservoirs should, if possible, be impounded during the winter months. This is desirable for several reasons.

When impoundment is initiated and completed during the winter months of December or January, flats and shallow productive areas are covered before there is an extensive growth of grass or shrubs. This practice is of primary importance for malaria control. It also prevents extensive growth on the flats, of plants which on decomposition add to the richness of the water. These growths may also cause the extensive production of blooms and taste- and odor-producing organisms.

Winter impoundment is desirable from the wild life standpoint because the reservoir is thereby filled before spawning activities of the most important game species take place. In this way, the valuable game species are given a good start in the first year of impoundment, and fishing in the reservoir is much better during the first two years.

Drawdown

Time, extent and character of the drawdown influence productivity. From the standpoints of malaria control and wild life, water levels should be kept high and stable in the spring and as far into the summer as possible.

Spring drawdowns that expose large, flat areas of the reservoir bottom may result in prolific marginal growths of aquatic, semi-aquatic or marsh vegetation. Many plants are unable to initiate growth until they are dewatered, but even short drawdowns allow them to sprout. Once growth is initiated, these plants continue to grow even though they may subsequently be flooded. Early spring drawdowns or fluctuations with recession, therefore, tend to produce in the zones of fluctuation of many reservoirs dense stands of annual plant growths, which upon decay produce periodic peaks of richness that may hinder the control of taste- and odor-producing organisms. In many reservoirs that have extensive flats, drawdowns which begin in the early spring and progress throughout the summer, result in dense growths of annual vegetation on the exposed flats.

Withdrawal Level

The level at which water is withdrawn from a reservoir is also of importance. Removal from the upper portion of surface layers often results in stratification during the summer months. Removal from the bottom of the reservoir, however, tends to remove the water as a unit, and stratification usually does not occur. Shortly after the construction of Wilson Reservoir, for example, stratification was found to be very pronounced. Under the TVA schedule of operations, however, there is no stratification of Wilson Reservoir during the summer months and, in September 1938, there was only 0.5°F. difference in temperature between the surface waters and those at a depth of 85 ft. Oxygen was present in adequate quantities at all depths.

Under certain conditions, reservoirs may serve as areas in which organic materials are utilized by the aquatic life to such an extent that taste and

odor problems do not arise in the effluent water. Yet it should be recognized that reservoir employment to utilize organic wastes and other elements causing the growth of algae or other taste- and odor-producing organisms must be carefully governed.

Transfer of Pollution

There are a number of factors that can result in the transfer of pollution considerable distances downstream. Organic wastes entering reservoirs which are turbid, or which have side streams that make them turbid, may be acted upon and broken down by bacteria which do not require light. Bacterial activities convert the wastes into products which are normally usable by phytoplankton, but which cannot be utilized because of a lack of light. These may sometimes be transported considerable distances before the water clears sufficiently to allow the penetration of sufficient light for the growth of phytoplankton. Undesirable blooms, with resultant taste and odor problems, may then be produced far from the sources of pollution. It should also be recognized that phytoplankton blooms in a reservoir may influence the character of the water supply for great distances downstream because, even though the algae are killed upon entering the stream, their decomposition products may be carried many miles before they are broken down or oxidized into materials which are not objectionable.

Rainfall

The amount and character of the rainfall exerts an influence on algal growths. If heavy rains and floods, with their resulting turbidity, all occur during the winter months, while the summer rains are light and the water becomes clear, algal populations will be much larger than they would be if conditions were reversed.

Returning irrigation water may increase the fertility of a stream or reservoir appreciably and thereby influence the growth of microorganisms. Raw sewage or sewage plant effluents serve as sources of growth-producing materials, and in small water areas usually result in blooms at some time of the year.

Unstable conditions and great changes in water levels often disturb or reduce normal aquatic populations. If large portions of the normal population are killed off periodically, organisms having short life histories may increase in great numbers. Undesirable blooms can thus occur before they can be controlled by the predators or competitors which keep them under control in a well balanced population. One of the valuable controls for algal blooms is a well balanced aquatic population.

An aquatic biologist or algologist with a knowledge of soils and their effects on the growth of algae, actinomycetes and other taste- and odor-producing organisms should be consulted to insure the proper selection of reservoir sites that are to be used for water supplies. Although much more must be learned before the problems can be met adequately, a few measures which can be taken currently in the selection, construction and operation of reservoirs for water supplies are listed below.

1. Whenever possible, a reservoir site should be selected where the soil is poor and where the sides of the reservoir are steep, so that there will be a minimum of flats and shallow bays favorable to the growth of aquatic vegetation.

2. The addition of rich silt to the reservoir should be prevented through the control of erosion on the watershed by terracing, strip and contour farming, maintaining soil cover, planting winter cover crops and controlling grazing, fires and lumbering operations.

3. The operation of the reservoir should limit water fluctuations, especially during the spring and early summer. This practice will prevent extensive growths of semi-aquatics on exposed flats. Growths of this sort add organic materials which may be conducive to the growth of actinomycetes or other undersirable organisms.

4. The operation of the reservoir should maintain ecological conditions which are favorable to permanent aquatic populations of the climax type, so that populations of short life history forms are kept within bounds. Recurring conditions unfavorable to the former result in huge populations of these latter forms, some of which may produce objectionable conditions. Under favorable conditions, blooms of these organisms develop rapidly when their natural predators and competitors have not yet become established. It is because of this fact that chemical control, which is nonselective, may complicate the taste and odor problem.

Conclusions

In order that the algae and other organisms in water may be controlled more efficaciously, there appear to be at least four major problems which must be given considerable study and research.

The first of these is a comprehensive and accurate biological survey of streams, lakes and reservoirs whose waters are being used by cities and towns. This survey must include a comparison of the biota of natural and of polluted water. The headwaters as well as the main body of the stream or lake must be examined. The genus, species and even variety of forms must be identified by experts. This primary and basic research cannot be left to general workers who have no background for making the fine distinctions among the many kinds of microorganisms. The survey must be carried on over all seasons of the year. Data on the chemical and physical analyses of the water are also absolutely essential.

The second problem is the pure-culture study of each alga, actinomycete and other taste- and odor-producing organism found to be common, or in some other way significant, in the water. The employment of pure cultures has been an essential part of bacteriology for many years, but only meager use has been made of them on the taste- and odor-producing forms. The work will be slow and tedious, but it is necessary if the specific growth requirements of each kind of organism are to be learned. Although the technique of obtaining pure cultures of algae and actinomycetes has been improved and simplified in recent years, it still requires the services of workers who are highly skilled in the procedure.

The third problem is the recognition of indicator forms among the algae. With bacteria, one learns to use such groups as the coliform as indicators of specific conditions in the water. Routine work in water laboratories can thereby be limited to a study of a comparatively few forms which have been so selected as to offer a fairly complete picture of the condition of the water. The particular treatment to which the water is subjected is determined after tests for the indicators have been made. Although a number of algae are already recognized as indicators of general con-

ditions of water, much basic research is needed to select forms which can be relied upon to give specific and important information on impending changes in the algal population of the water.

The fourth of these problems is the establishment of a regular, well planned, permanent, year-round sampling service for all important streams, lakes and reservoirs which, like the weather bureau, can supply water laboratories with periodic information about a body of water throughout its whole course. Interpretations predicting the nature of the water for coming periods should also be provided by this medium. A service of this type can help not only water purification laboratories, but also the many other concerns and individuals interested in the use of each particular stream, lake or reservoir. Such a service would replace the inadequate hit-or-miss sampling methods used at the present time.

If research in these four important fields is to be carried out on a large scale, it will need the enthusiastic interest and support of all who are concerned with water purification plants. It will require the generous financial backing of many individuals and groups. Since the primary work is basic research, it must be handled in a manner that will encourage rather than discourage the necessary services of qualified experts in the fields of phycology, limnology, biophysics and biochemistry.

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Quality Control of Industrial Water

By Clarence D. Adams

A paper presented on February 8, 1951, at the Indiana Section Meeting, Indianapolis, by Clarence D. Adams, Chem. Engr., Colgate-Palmolive-Peet Co., Jeffersonville, Ind.

THE major difference between the control of industrial and municipal supplies is that control of the former is for a specific purpose. Industrial water has work to do; the control of its quality, therefore, depends upon the particular job or jobs which it will be required to perform. Its control, instead of being based upon public health standards, has as a foundation the definite requirement for which good performance is demanded. Quality control of an industrial water supply is employed to produce the best possible water for the particular purpose desired; and to produce it at the most economical cost.

Details of the control of such factors as turbidity, pH, hardness, bacteriological quality and discussion of the chemistry of scale formation and corrosion are purposely omitted to avoid repetition. The water works profession developed these. The industries have borrowed them and are using them to good advantage, with, of course, occasional refinements.

Uses of Industrial Water

It seems most appropriate, here, to enumerate the tasks which industrial water is required to perform and to cite specific examples.

In a broad sense the industrial uses of water can be classified as:

1. Steam and power production
2. Heating, by means of steam or hot water
3. Cooling, by once-through flow, closed systems employing shower condensers or cooling towers, refrigerated water closed systems and vats.
4. Processing, including canning, ice manufacturing, beverage makeup and a large group of chemical procedures
5. Washing (as done by a wide variety of industries, including the canning, textile and gas industries)
6. Classification, as in the ore and canning industries
7. Vacuum production, through the use of jets and barometric condensers
8. Fire protection
9. Personal use by employees.

Problems of Industrial Users

Not all industries employ water for all of the above purposes, but usually most of them find application. Time does not permit specific detailing of the intricacies of quality control of the water for each specific use. There are, however, certain problems that confront the industrial users of water:

1. Scale formation on heated surfaces, or in pipes, valves, jackets and vessels handling heated water
2. Chemical and bacteriological corrosion of equipment in contact with either cold or heated water

3. The growth of slime on or in condenser tubes, cooling towers, shower condensers, cooling rolls, or piping carrying cold or warm water.

The tools which an industrial plant uses to maintain the quality of its water are not kept secret. It is common knowledge to the water works profession that softening by chemical treatment, ion exchange or demineralization will eliminate most scale formation, and that treatment by such materials as phosphates will help to alleviate it. The profession also knows that pH control, the use of inhibitors, protective coatings and cathodic protection, and the elimination of carbon dioxide and dissolved oxygen, are all useful in corrosion prevention; and that chlorine, phenates and other organic compounds are used for slime control.

Case Histories

Instead of discussing widely published facts, the remainder of this discussion will therefore be devoted to the presentation of eight specific examples of industrial quality control which the author has experienced. They are listed below.

1. Cooling Rolls.

The efficiency of cooling was failing at a rapid rate and resulted in the production of substandard product and subsequent production loss.

An investigation revealed that sprays were partially clogged with corrosion products and organic growth, and that there were slime growths on the inside of the cooling rolls.

Normal operating conditions are being maintained since the piping was cleaned with an inhibited acid. The difficulty is being controlled merely by applying enough sprays each week to kill any organic growth that may have developed.

2. Closed Hot Water System

The hot water tracing system included a pump, heat exchanger, piping, tracing lines, jacketed vessels and hot-water storage tank, all within a closed system.

Investigation revealed that scale formation on the heating coils, and stoppage of lines and jackets by corrosion products might prove troublesome if not controlled.

The entire system was first cleaned with inhibited acid, and daily treatment with sodium hexametaphosphate * is being employed for the combined purpose of scale and corrosion prevention. A long enough record of this treatment is not yet available to allow the drawing of any definite conclusions.

The present control consists in maintaining the proper sodium hexametaphosphate concentration in the heated water.

3. Cafeteria Hot Water System

Scale was found to be forming rapidly on steam coils, restaurant equipment and in coffee urns. Since heated softened water is known to be corrosive, Micromet † treatment was employed.

Results, although not perfect, have been encouraging.

Since Micromet is a compound that is theoretically dissolved at the rate of 25 per cent of its original weight per month, regardless of the amount of water coming in contact with it, the

* The sodium hexametaphosphate used was "Calgon," a product of Calgon, Inc., Pittsburgh, Pa.

† Also a product of Calgon, Inc.

Micromet dosage is computed by taking the difference between monthly water meter readings and dividing by 12,000.

4. Refrigerated Water System

The system includes a pump, cooling rolls, jacketed vessels, and piping, all in a closed system. An investigation revealed that active corrosion was taking place.

The quality of this water is maintained through the use of Sodium Chrome Glucosate compound.* Concentrations of compound are kept within the range of 175 to 225 ppm. The results have been satisfactory over a considerable period.

Control is achieved by determining the compound concentration weekly and adding the required replacement as needed.

5. Shower Condenser

The condenser includes pump, piping and compressor cooling unit. An investigation revealed a scale formation on the tubes which Micromet was used to treat. Phosphates are a plant food, however, and slime was soon growing profusely in the shower condenser, with resultant stoppage of the pump intake screen and spray nozzles, causing considerable production loss.

Chloride of lime treatment was employed to kill the slime growth. Results were very satisfactory, but excessive foaming caused by airborne dust contamination necessitated the discontinuance of this type of treatment. Chlorine gas treating equipment was also undesirable because of the proximity to a heavily populated working area.

* A product of D. W. Haering & Co., Inc., San Antonio, Tex.

Dowicide "G" † treatment was substituted and gave excellent initial results, but organisms carried by the air into the moist areas above the sprays in the shower condenser developed an immunity to the compound after several months. Extremely heavy growths of slime resulted.

The system was next treated with chlorine solution taken from discharge hose of a chlorinating mechanism. Sodium Chrome Glucosate was added to the water for temporary control of slime and gave fair results.

Sterimine ‡ was then tried with good initial results, but then also failed. It was suspected that the immunization of organisms had developed to such an extent that it would be necessary to change treatment compounds at regular intervals for the best control.

Later on, however, it was determined that the foaming not attributable to chloride of lime treatment was caused by a reaction between the carbonate scale and the chlorine which released carbon dioxide gas. Accordingly inhibited hydrochloric acid was used to remove the scale, and chloride of lime treatment was resumed, with successful results.

6. Poultry Processing Plant

A new industry was attempting to employ natural sedimentation followed by filtration through porous concrete blocks for the production of water from a surface source. With this minimal treatment the water was used in processing chickens for the open market, a practice which resulted in repercussions from the health agencies.

† A product of The Dow Chemical Co., Midland, Mich.

‡ A product of Wallace & Tiernan Co., Newark, N.J.

Water meeting U.S. Public Health Service bacteriological standards was produced by temporary use of alum, soda ash and chlorination.

The problem was complicated by the following factors:

1. The source is a relatively small creek in which the water has an alkalinity varying from 8 to 40 ppm. and a pH varying from 6.5 to 7.5.
2. Sodium hypochlorite was used, but at times the addition of the required amount for chlorine residual of 5 ppm. raised the pH sufficiently to render the chlorine ineffective. High-test hypochlorite * was found to give better results.

The control found necessary is frequent pH, alkalinity and residual chlorine tests followed by bacteriological analyses of water samples. A more elaborate water purification plant has been designed and soon will be under construction.

7. Cooling Tower

The cooling tower includes barometric condensers, pumps, cooling units, piping and accessories.

A serious corrosion problem had developed and was accelerated by the following:

1. Acid vapors that were pulled from a flash cooler lowered the pH.
2. It was necessary to expose surfaces to the air on week-end shutdowns.
3. Sulfate-reducing bacteria and other organic growths were present in great numbers in the water.

These conditions caused occasional shutdowns for equipment repair, and for heat-exchanger tube cleaning. A well known compound manufacturer was consulted to help solve the problem. His laboratory reported such numerous and diverse forms of organic life present that the manufacturer flatly stated that he had no suitable effective compound.

It was thought that because of the nature of the noncondensables carried over from the flash coolers to the cooling water, the chlorine demand of the water would render chlorination too costly. It was decided, however, to give the process a trial.

During the first few days of the test, the chlorine demand was very high for the amount of water (900 gpm.) being circulated. The chlorine soon took hold, and the organic growth was eliminated, thereby reducing bacterial corrosion. Chlorine was used at the rate of 90 lb. daily for periods of one hour a day. A pH controller using caustic solution was installed and the problem was brought under control.

Quality control tests thus developed into those for residual chlorine and periodic checking of the pH controller. Many chlorine, pH and total solids determinations were necessary, however, before the control was established.

After a long period of successful operation, process changes, including cooling tower changes, rendered this problem very difficult indeed. Caustic, instead of acid vapors, were predominant contaminants of the cooling water. This situation caused the chlorination to be ineffective, and ammonia vapors complicated matters. The pH controller was changed from caustic solution to sulfuric acid.

Slime problems, held in check by winter conditions, developed with the advent of warmer weather. Operations were stabilized with a pH be-

* The high-test hypochlorite used was a product of Mathieson Chemical Corp., Baltimore, Md.

tween 8.1 and 8.3. The water has been brought under control by the use of chlorine at the rate of 100 lb. per day for a period of two to three hours daily.

It is expected that alcohols from processes to be instituted, however, will affect the control problem and require a change in present procedures.

8. Hot Water System

The system includes pump, heat exchanger, hot water tank, automatically operated valves, small piping and sprays in automatic centrifuges.

In this system, approximately 3,000 gpd. of well water of approximately 342 ppm. hardness are heated to 190°F. and used in the centrifuging equipment. The high temperatures involved produced serious scaling. The steam coils became heavily coated with scale on the water side. Scale built up to a depth of more than an inch on the inside of the hot-water tank and also was heavy throughout the piping. The automatic valves needed frequent servicing.

Treatment methods were limited because the water used in the centrifuges was given subsequent processing. Softening was considered, but because of the corrosiveness of the softened water, use of that process was postponed.

An Electromatic Electronaire,† a special galvanic couple, was placed in the hot water tank on trial. The theory of the operation of this unit is that enough electrical potential is produced to discharge the scaling particles electrically, thereby permitting them to settle freely or carrying them on through the system without allowing them to build up into scale.

† A product of the Electromatic Engineering Corp., Louisville, Ky.

After a month's use of the unit, inspection revealed quite marked results. Most of the scale has been removed from the walls of the hot water tank and only a thin coating remained. The servicing of the automatically operated valves was reduced to a necessary minimum.

Continued operation, however, revealed that the thin coating on the hot water tank walls was not eliminated and that gradual building up of scale, within the piping system and on the valve seats, reduced the amount of water delivered to the sprays.

Arrangements have been made to use steam condensate in this system. No heater and very little piping will be required, thereby virtually solving the problem.

The control of this problem at present consists in regular inspections of the equipment, including the Electronaire. The sacrificial element of this unit must be replaced approximately every six months.

Summary

It will be noted that in the examples presented, control of the quality of the water used by the various industries concerned has not been elaborate. This is partly because of the scope of the author's experience, and partly because of the fact that, in industry, controls are kept to a practical and necessary minimum. The individual in charge of water supply often has many other duties to perform. Control laboratories also are established for production control. Special control tests are always added burdens to laboratory personnel. A minimum amount of testing for good control of industrial water is therefore desirable.

In the power and other industries, where more frequent and sometimes

elaborate tests are of major importance, laboratories under the supervision of highly trained technicians are often advantageous and even necessary. The work of such laboratories has been widely published. It has been the author's intent merely to present a few specific experiences in order to acquaint those concerned with some of the everyday problems occurring in the average industry.

The tools to be used in the control of an industrial water are common knowledge to the water works profession. There is one exception: poisonous materials can occasionally be used to solve an industrial water problem.

Before the proper tool can be selected by any industrial user of water the following questions must be answered:

1. Will the proposed method be most effective under the conditions encountered?

2. What will be the daily requirements?

3. How much attention need be applied to control?

4. Will the method create a taste, odor or color problem for any product?

5. Will it promote organic growth?

6. Will the method be economically feasible?

7. Will it be safe for personnel to handle or to come in contact with the treated water?

8. Will the water, if chemically treated, be used further in any other department? If so, will chance contamination by the treatment chemicals be ruinous to the material being produced?

Planning Expansions by Forecasting Public and Industrial Requirements

By Paul D. Cook

A paper presented on February 8, 1951, at the Indiana Section Meeting, Indianapolis, by Paul D. Cook, City Manager, Painesville, Ohio.

PLANNING is a general term denoting a process that culminates in a proposed course of action or procedure. It is a dynamic process as it requires the meeting of ever-changing requirements of residential, commercial and industrial development for adequate supplies of water. In no sense and at no time in the thinking of a progressive and an alert water works administrator is the process of planning static.

William Ludlow, former Chief Engineer of the Philadelphia Bureau of Water, in his annual report in 1885 said (1):

> The creation and maintenance of a system of water supply to a great modern community is practically a never-ending problem. The needs of each generation so largely transcend not alone those of the preceding one, but even the estimates which could then have been formed of the future requirements, as almost invariably to exceed reasonable anticipations and far outrun the capacity of existing constructions, even with considerable additions from time to time.

Planning Process Never Ends

Parallel experiences have been observed over the years in all the larger cities of the nation and, to no lesser degree, in smaller cities and communities. It is therefore a fundamental premise that planning for the future in water supply is a never-ending process. It is one of the activities in the profession that never stands still. One either goes forward by keeping abreast with the growth, development and changes in the community and by constantly planning and repeatedly revising the plan; or one slips backward with the self-satisfied feeling that he is prepared for the future because his plan for expansion has been completed. Today's plan must be revised tomorrow to meet one or more unanticipated developments from yesterday's experiences.

The A.W.W.A. Board of Directors at its January 1950 meeting in New York expressed serious concern over the failure of some of the larger cities to recognize the importance of long range planning for an adequate supply of water. Serious emergencies, too, often arise because the recommendations of progressive water supply administrators are subordinated to some more politically expedient program. This practice was decried by a board statement urging long range planning for water supply systems, and was further discussed by the Water Resources Division at the 1950 Annual Conference of the Association in Philadelphia.

During the same month—January 1950—the annual meeting of the

American Society of Civil Engineers was in convention in New York. The Sanitary Engineering Division staged a discussion which Malcolm Pirnie opened with the following remarks in discussing the New York City emergency (2): "There is no water shortage—the current difficulty being merely in the delivery of some of the available supply in satisfactory condition to the places where it is wanted."

He was not referring to a need for an expanded distribution system as water works men commonly know it. Rather, he referred to a need for determination of safe yield of stream facilities, combined with the chemical and bacteriological control of such resources already available, yet uneconomical for use because of pollution. Long range planning by the world's largest metropolitan area apparently had not then been practiced in sufficient degree to avoid a near catastrophe.

Determining Future Needs

In planning future expansions to meet public and industrial requirements, it must first be determined with the greatest possible degree of accuracy just what future requirements will be. A water supply system is appraised by its ability to produce and to deliver to all the points of consumption, and at any required time, water of satisfactory quality, sufficient quantity and adequate pressures to satisfy the domestic, commercial and industrial demands of the community, and the need for fire protection.

It becomes necessary, therefore, to estimate accurately the future growth of population and the probable commercial and industrial development of the area under consideration. This information, coupled with experience-records of production and distribution of the existing system, makes possible a predicted average rate of demand for the anticipated community of the future. On this basis, the proper capacities of intakes, pumping stations, purification plants and transmission or supply mains may be established. For well fields, the required yield and the necessary recharge rate are determined. With the impounded surface supply, the minimum average satisfactory yield of the watershed is calculated as a requirement for adequate supply. Since capacity requirements determined from empirical data are reflected in construction, operating and maintenance costs, it is no trifling responsibility that the planning engineer assumes in preparing his estimates of community development. Valid and adequate data must be collected, carefully evaluated and then intelligently prepared for presentation.

Building for Later Change

It is also necessary to recognize that certain of the facilities, the requisite capacities of which have been established, can be designed and constructed in a manner that will permit future expansion on a unit basis. These facilities must therefore be planned for a relatively short capacity life. This statement refers to pumping stations, major operational facilities of filtration plants and well field development. Conversely, functional parts of a system such as intakes which may extend several thousand feet into a body of water, impounding reservoirs or large transmission mains do not lend themselves economically to periodic expansion or enlargement and must therefore be designed to accommodate longer futurity. No specific rules of

procedure, however, can be established for the economics of varying futurities because each community's water supply system is the end result of development that depends upon the characteristics of location, topography, soil structure, climatic conditions, and many other factors peculiar to that particular area.

Population Forecasts

Forecasts of population for relatively short periods in the future can, under normal conditions, be made with reasonable accuracy. But when the unusual occurs, predictions covering a short span of years can be appreciably in error. The hazard of obtaining inaccurate forecasts of population and industrial development increases in direct proportion to the additional length of futurities required.

The water works industry unfortunately must make the most difficult and hazardous forecast of development in establishing capacities of those parts of the system which are generally the most costly. This situation obviously requires that careful study be given to the available data on population trends and that great care be exercised in evaluating the characteristics surrounding industrial development in order that the results obtained may be as accurate as sound judgment permits.

Sources of Data

Decennial census data published by the U.S. Bureau of the Census, which are available at any local library, are a dependable source of information from which population trends may be established. Another valuable source, and a relatively accurate one, is the record over a long period of years of the number of active water service connections in the particular community. These figures establish annual experiences that are even more revealing than the relatively infrequent reports of the federal census.

Data compiled on a monthly or quarterly basis ordinarily produce more accurate results in establishing trends than those gathered less frequently. A ten-year statistical study is the proper time coverage for short range forecasting, while several decades should be carefully studied when long range predictions are to be made.

Building permits, conversion and demolition records, and birth and death records of the local health department are all valuable sources of information which are available in most municipalities. Migration trends can be established from school enrollment statistics and from unemployment compensation records. Local chambers of commerce frequently accumulate information for market forecasting that is available to municipal authorities.

Data Evaluation

When the trend data have been assembled the important step must be taken of evaluating and using them—of choosing the most effective technique available, in the judgment of the planning engineer. Three basic procedures of forecasting are currently in use: extrapolation, correlation and analytical techniques (3).

Extrapolation

Extrapolation is the extension of a plotted series trend curve or line beyond its last plotted point. Such extrapolations may be made either graphically or mathematically, and, theoretically, may be projected as far into the future as desired. Caution should be

exercised, however, in the use of this method, the chief virtue of which is its simplicity. It will be correct only if the causes of past growth and development continue to operate in the future. For this reason, its failures have been said to have exceeded its successes and its use has fallen into relative disrepute except in some business applications of very short range forecasting.

Correlation

Correlation is a method of determining and applying to the forecast the degree to which changes in one variable are associated with changes in another. The method in its simple form starts with the construction of extremely useful charts, called "scatter diagrams," in order that any relationship between two variables may be established. Any good text on statistical methods will explain this procedure (4). Simple and complex forms of correlation are currently in use by statisticians for the purpose of forecasting.

An illustration of the correlation technique is a study (3) of the population of Flint, Mich., made in 1947 under the auspices of the University of Michigan. A very close correlation was found to exist between manufacturing employment in Flint and durable goods employment on a national basis during a thirteen-year period, 1928–40. A national forecast for 1950, published by the Bureau of Labor Statistics in March 1947, was inserted into the formula describing this relationship. The equation, solved for Flint, gave an estimate for 1950 of local manufacturing employment. This was expanded to an estimate of total population by applying predetermined relationships between the labor force and the total population.

Analytical Techniques

Analytical techniques are varied. The choice among them depends upon statistical data available and the nature and anticipated use of the desired results. A few of the analytical techniques are the economic rhythm method, the specific historical analogy, the cyclical sequence method and the cross-cut analysis (5).

It is nevertheless in order to warn against complete dependence upon any exclusively statistical method of forecasting or planning. A broad factual knowledge of patterns and trends in water consumption is needed. An understanding of underlying economic processes is of basic importance. One who is searching for a magic formula that will enable him to forecast automatically is foredoomed to disappointment and failure.

Daily Fluctuations

By establishing the maximum, minimum and average daily demands, after having determined the future total average requirements, calculation will produce the plant capacity results desired. Daily fluctuations in water demand are present in all water systems and must be taken into account in determining capacity requirements. In planning for the future, existing ratios of variation can be applied to future average requirements as determined by one of the above methods of population and development forecasting. It must always be kept in mind, however, that the soundness of applying existing ratios to future requirements is dependent upon the similarity of past growth and future anticipated development.

A satisfactory procedure, if this method is followed, is that of first determining the average daily produc-

tion of filtered water in the present plant for each year over a period of years. Three separate ratios for the period are then determined: [1] the average day of the maximum month to the average day for the year; [2] the maximum day of the year to the average day; [3] the minimum day of the year to the average day.

The necessity of considering hourly rather than daily fluctuations will be dictated by the adequacy of distribution storage. In general, distribution facilities, including local storage and pumping stations, should be planned to provide for the maximum hour of consumption. Supply facilities, however, including well fields, intakes and filter plants, should be planned to meet the demands of the maximum daily draft.

The standard grading schedule (6) of the National Board of Fire Underwriters reflects firefighting needs for communities of various sizes. Reference to this schedule will determine particular needs. Good engineering practice will dictate provision for maximum fire flow simultaneously with normal usage at the average rate of the maximum day.

Causes of Errors

Appreciable or substantial errors can occur in predictions for the future when unusual developments occur. A new industry which has need for enormous quantities of process water might move to the area under study. Construction of a large military camp or arrival of a new industry bringing into or near a small city a large labor force are examples of governing factors. These possibilities are all relative in their importance to communities because the factors of existing capacities, availability of additional water resources and economic feasibility of expansion require individual study and evaluation.

Recent studies have been made of the relationship between industrial demands for process water and water resources. It has been said (7) that the total industrial demand is one of the most important factors contributing to local water shortages which have recently occurred.

Other Necessary Studies

It is evident that much study must be given to the limitations of watersheds, recharge rates of available well fields and other factors governing water resources before location of prospective industry may be encouraged. Where critical or potentially critical situations exist, further industrialization should be discouraged, unless it is economically practicable to tap additional and totally different resources. The progressive and alert water works executive must keep himself adequately informed of the limitations of his source of supply, his production facilities and his distribution facilities. He must have his plans laid well in advance of current needs and be quick to recognize any unusual circumstances that will require revision of those plans.

Danger of Misinterpretation

As it may be advisable to add a final word of caution to refrain from overvaluing the available statistics, and to show care in qualifying forecasts, a quotation from Mark Twain's *Life on the Mississippi* is pertinent:

> Now, if I wanted to be one of those ponderous scientific people and let on to prove what had occurred in the remote past by what has occurred in a given time

in the recent past, or what will occur in the far future by what has occurred in late years, what an opportunity is here! Geology never had such a chance nor such exact data to argue from! Nor development of species, either! Glacial epochs are great things, but they are vague—vague. Please observe: In the space of 176 years, the lower Mississippi has shortened itself 242 miles. That is an average of a trifle over one mile and a third per year. Therefore, any calm person who is not blind or idiotic can see that in the Old Oolitic Cilurian Period just a million years ago next November, the lower Mississippi was upward of 1,300,000 miles long and stuck out over the Gulf of Mexico like a fishing rod; and by the same token, any person can see that 742 years from now, the lower Mississippi will be only a mile and three-quarters long and Cairo and New Orleans will have joined their streets together and be plodding comfortably along under a single Mayor and a mutual Board of Alderman. There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of fact.

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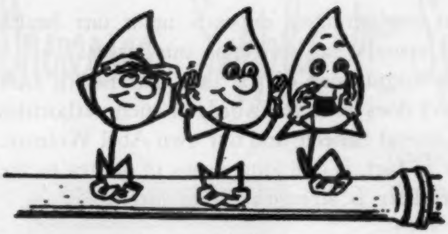


Percolation and Runoff

Salmon, water and people are apparently all safe from the effects of residual radioactivity from the Hanford atomic energy works at Richland, Wash. Some 25,000 test salmon, 4,000 samples of drinking water and 900 from test wells, 200 experimental ewes and 12,000 chunks of atmosphere per year go to show that nobody has a thing to worry about in the exhaust or effluent of Hanford's atomic fuel or plutonium production. Water from the Columbia River, important to the operation of the works, gets well radioactivated in the process of cooling the atomic reactors, but before it is returned to the river its charge is reduced almost to the vanishing point. Continuous sampling shows the water to be safe and continuous spawning shows the salmon to be at least thriving in the area. As for people, General Electric scientists indicated that "one person would have to eat, at a single sitting, 100 lb. of Columbia River salmon caught just below the Hanford works to take into his body a noticeable amount of radioactive material." Just who could get away with catching 100 lb. of salmon just below the Hanford works isn't indicated, but we'll bet the FBI and the Washington Fish & Game Commission could become quite nasty about the whole thing. And if, through some jurisdictional dispute or other, we were to get past that stage, who would clean the mess!

Eau chaud! Hot water, that is, is what, according to the Gas Appliance Manufacturers Association, Inc., our health and our strength depend upon. And who are we, who work with the really basic stuff of hot water, to complain about a 32-page paean. What we're talking about, of course, is GAMA's recent booklet, *Our Health . . . Our Strength,* which purposes "to inform as many people as possible of the never-ending menace of dirt and disease; to show their deadly peril in time of emergency; to give practical suggestions for our counterattack through constant watchfulness; to emphasize the miracle work of simple preventives and remedies; to rouse every reader to do his small part, privately and publicly, for Operation

(*Continued on page 2*)

(*Continued from page 1*)

Survival," all on the basis that our strength depends upon our health depends upon our hot water! Depends, say we, upon our water.

Of course the booklet takes cognizance of the fact that health isn't quite as simple as a handwash, and does so in the words of such authorities as Stuart Symington, Surgeon-General Scheele and our own Abel Wolman. The whole brochure, as a matter of fact, is one long series of quotes to the eventual point that in hot water there is strength. *Eau fort!*

Getting into hot water and health reminds us of an advertisement in the Newark, N.J., *News* of last June, which featured Hot Springs (Ark.) water as practically panacean. "In most observed cases," bubbled this blurb, "Mountain Valley Water: (1) rapidly eliminates systemic waste; (2) increases subnormal kidney function; (3) supplements our supply of needed minerals; (4) it is delicious and pleasant, with no sharp action or harsh reaction." Seems as if this hot water, too, has some association with gas. Almost makes one want to run . . . to his nearest authorized dealer.

The flowering of fluoridation may be advanced slightly by the conference of state health department dental directors, held at Washington June 6–8, to discuss with U.S. Public Health Service and Children's Bureau representatives. The conference was called with the open intention of discussing methods of encouraging communities to fluoridate their water supplies as soon as possible, and Surgeon General Leonard A. Scheele took as the basis for his remarks the observed effects of demonstration projects in various cities, citing reductions of dental caries of as much as 65 per cent. The state dental directors had endorsed fluoridation a year ago, and were mainly concerned at this meeting with how to manage technical details, educate the public and municipal officials and evaluate the results of the fluoridation.

"Tomayto" and "tomahto" are no trouble at all compared with "water works" and "waterworks," at least as far as A.W.W.A. is concerned. We've always felt a little hurt when people called us the American Waterworks Association—primarily because we thought they knew us better than that—but we never became really exercised about the name-calling until we reached Miami last April and found ourselves in Joe Somebody's newspaper column. Not enough that he should call us American Waterworks Association, he took us typographically to task for using A.W.W.A., when A.W.A. instead properly initialed his idea of our name.

"Any publicity" may be "good publicity," but is it even publicity if it never mentions our name?

(*Continued on page 4*)

(*Continued from page 2*)

A tribute to the late Charles P. Hoover, written by F. H. Waring, chief sanitary engineer of the Ohio State Dept. of Health, is being featured in the 1950 annual report of the Columbus, Ohio, Div. of Water. The text of this deserved eulogy to a beloved leader of his profession is reprinted below:

In Memoriam

CHARLES P. HOOVER

City Chemist, Division of Water, 1908–1950

In the death of Charles P. Hoover, Columbus suffered a loss the extent of which comparatively few people realize. Those who were fortunate enough to have been associated with him during his lifetime service to the city are they who are aware of that loss. Mr. Hoover's entire professional life was devoted to the art of municipal water purification and softening. In this field he was both pioneer and leader, recognized throughout the state and nation as "tops" in his profession. The degree of Doctor of Engineering conferred upon him by Ohio State University was only one of many professional recognitions accorded him for his depth of understanding and achievement in his chosen field of water treatment.

Mr. Hoover's life work began and ended at the Columbus water purification and softening plant. Upon completion of the Dublin Road plant in 1908 he was employed as one of the chemists. Within a few years he rose to chief chemist, and lately to water superintendent. Columbus became the first city in the nation and the third municipality in North America to purify and soften its municipal water supply using the so-called lime-soda process. Mr. Hoover was co-discoverer with Sir Alexander Houston of London, England, of the sterilizing value of the excess lime method of water treatment. The fame of Mr. Hoover's discoveries and innovations in municipal water purification as practiced at Columbus is largely responsible for the present day large number of similar municipal water treatment works throughout the state and nation. Ohio now has more such municipal plants than any other state, amounting to nearly one-fourth of all such plants in the United States—a tribute indeed to the man who guided Columbus in this endeavor for all these years.

No municipality was too small, no water treatment problem too baffling, for Charles P. Hoover to devote of his time and energy so that the public might enjoy the best in drinking water quality. Municipalities large and small sought his advice and consultation. Many a water treatment works across the nation, from Los Angeles to St. Louis to Miami, bears the imprint of his thinking in its present-day design and method of operation. And to many a water works man he was known and is still remembered affectionately as "Charley" Hoover.

(*Continued on page 6*)

(*Continued from page 4*)

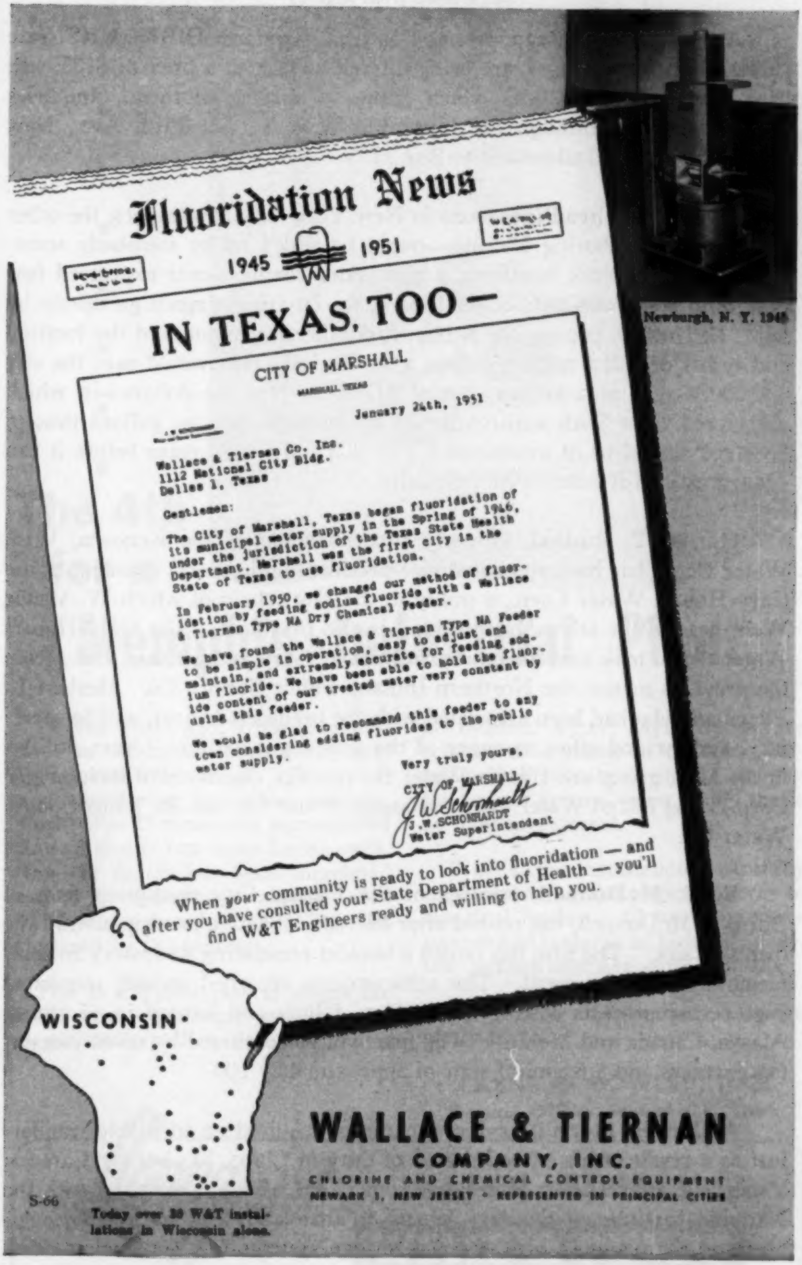
Investigations of distribution system water quality are being coordinated by A.W.W.A. Committee E5-2—Biological and Chemical Problems of Water Distribution Systems. Under the terms of a recent reorganization, the committee's primary objectives are to: [1] act as a clearing house for information on deterioration of water quality by facilitating the exchange of information among those working on similar problems; [2] assist in solving individual problems by drawing on the pooled experience of all operators; [3] coordinate and review papers on distribution problems and make recommendations for their presentation and publication; and [4] encourage the study of water quality control in distribution systems and suggest problems for study to water works laboratories wishing to cooperate in a general program for the control of water quality deterioration.

The committee is primarily a coordinating agency; papers resulting from any cooperative work may be published by the individuals responsible.

Those who are currently studying any phase of distribution quality, who are considering publication of a paper, who wish to communicate some pertinent fact or experience to the field, or who would be willing to assist in future programs for investigating chemical and biological water quality deterioration are requested to send details to D. W. Graham, Coordinator, Committee E5-2, San. Eng. Div., Box 3669 Terminal Annex, Los Angeles 54, Calif.

A new curriculum in sanitary engineering is to be instituted at Ohio State University, beginning with the fall semester. The course, which will be one of the options in civil engineering, will lead to the Bachelor of Civil Engineering and Master of Science degrees after five years of study. The course will be identical with other civil engineering branches until the third year, when specialized sanitary engineering courses will be introduced.

(*Continued on page 8*)


Fluoridation News
1945 1951
Newburgh, N. Y. 1945
IN TEXAS, TOO—
CITY OF MARSHALL
MARSHALL TEXAS
January 24th, 1951
Wallace & Tiernan Co. Inc.
1112 National City Bldg.
Dallas 1, Texas
Gentlemen:
The City of Marshall, Texas began fluoridation of its municipal water supply in the Spring of 1946, under the jurisdiction of the Texas State Health Department. Marshall was the first city in the State of Texas to use fluoridation.
In February 1950, we changed our method of fluoridation by feeding sodium fluoride with a Wallace & Tiernan Type NA Dry Chemical Feeder.
We have found the Wallace & Tiernan Type NA Feeder to be simple in operation, easy to adjust and maintain, and extremely accurate for feeding sodium fluoride. We have been able to hold the fluoride content of our treated water very constant by using this feeder.
We would be glad to recommend this feeder to any town considering adding fluorides to the public water supply.
Very truly yours,
CITY OF MARSHALL
J.W. Schonhardt
J.W.SCHONHARDT
Water Superintendent
When your community is ready to look into fluoridation — and after you have consulted your State Department of Health — you'll find W&T Engineers ready and willing to help you.
WISCONSIN
Today over 30 W&T installations in Wisconsin alone.
WALLACE & TIERNAN
COMPANY, INC.
CHLORINE AND CHEMICAL CONTROL EQUIPMENT
NEWARK 1, NEW JERSEY • REPRESENTED IN PRINCIPAL CITIES
S-66

(*Continued from page 6*)

A group of sixteen 10-in., 250-psi., standard IBBM NRS gate valves, with extra flanges, are being offered for sale at a price of $135 each by a firm in Norfolk, Va., which wishes to dispose of them. Inquiries should be routed through the Journal A.W.W.A., 521 Fifth Ave., New York 17, N.Y., and addressed to Box 71.

Two sets of headlines—one in New York City newspapers, the other in those of neighboring Newark—ought be added up by somebody sometime. In New York headlines, a new water commissioner expressed fear that, with reservoirs unfilled on June 1, the city might again go thirsty by fall. In Newark papers, the public works director announced the location and repair of half a million gallons a day in leaks that would save the city $20,000 a year at a survey cost of $12,000. Not the dollars—in which unmetered New York apparently has no interest—but the gallons thus to be saved should be of interest to a city that must wait years before it can again waste all it wants with immunity.

Harold T. Rudgal, formerly superintendent of the Kenosha, Wis., Water Dept., has been appointed vice-president and general manager of the Gary-Hobart Water Corp., a utility in the Mott chain of which W. Victor Weir, head of the other Mott utilities, is also president. The Gary-Hobart Water Corp. took over the water utilities at Gary and Hobart, Ind., from the previous owner, the Northern Indiana Public Service Co. Herbert L. Plowman, who had been associated with the predecessor firm, will be secretary, auditor and office manager of the new organization. Other utilities in the Mott group are Illinois Water Service Co., Northern Illinois Water Corp., Long Island Water Corp., Missouri Water Co. and St. Louis County Water Co.

R. E. McDonnell, founder of the Kansas City consulting firm of Burns & McDonnell, has retired after 53 years of active participation in the firm's affairs. The firm has issued a booklet recounting its history in commemoration of the event. The achievements recorded include municipal engineering projects costing 769 million dollars and located in 45 states, Alaska, Canada and Mexico. The firm will be continued by seven remaining partners and a technical staff of approximately 100

Arthur B. Morrill, having apparently acquired an incurable wanderlust as a result of his extended tour of duty in China, has left for Caracas, Venezuela, after a short interval at home. He will be associated with the National Institute of Sanitary Works in that land, advising design engineers on the planning of water and sewage systems for Venezuelan cities.

(*Continued on page 10*)

(Continued from page 8)

Waterborne outbreaks of disease occurred 25 times during 1949, according to the U.S. Public Health Service's annual study of outbreaks traceable to water, milk and foods. The 1,570 cases involved in the waterborne outbreaks represented a sharp increase of 951 over the 1948 total, although deaths declined from 4 to 3. Despite the more than doubling of the incidence in the two years, it was pointed out by Surgeon General Scheele that outbreaks attributed to both water and milk have declined by more than 50 per cent in the past decade. The statistics are compiled from reports of state and local health departments in the United States, however, and do not reflect unreported illnesses or outbreaks.

"Municipal Sewage Treatment Processes" is the title of a 16-mm. film released by the U.S. Public Health Service's Communicable Disease Center, 50 Seventh St., N.E., Atlanta 3, Ga. Intended to show public health sanitarians and professional trainees how sewage can be treated to avoid pollution of streams and menace to health, the 13-minute sound film is available for short loans, without charge, from the center; or copies may be purchased through United World Films, Inc.

(Continued on page 12)

(*Continued from page 10*)

The cost of materials constitutes 50 per cent of the total cost of new water system construction, according to a survey conducted jointly by the Department of Labor's Bureau of Labor Statistics and the U.S. Public Health Service. Labor costs comprise 30 per cent of the total, with the balance distributed among supplies, overhead, profit and equipment charges. The proportion allotted to materials is the same whether treatment plants or distribution pipelines are being analyzed. Of the water treatment plant costs, 20 per cent represents purchases of key metal products (such as pipe, fittings and reinforcing steel), 15 per cent is for metallic machinery and equipment to operate the treatment processes and 10 per cent is for premixed concrete. For pipelines, one-third of the cost covered metal products (chiefly the pipe itself, and fittings) and 10 per cent covered asbestos-cement, stone, clay, glass and other products.

Sewage plants were also studied, and were found to require a somewhat smaller outlay—about 40 per cent—for equipment, although labor costs remained at the same proportion. The itemized tabulation for water works is given below:

*Construction Expenditures for New Water Supplies**

Item	Expenditures		
	Treatment Plant	Distribution System†	Weighted Total‡
	$1 million units		
Labor	**301**	**317**	**315**
Overhead, profit and equipment charges	**176**	**170**	**171**
Supplies	**19**	**19**	**19**
Explosives	§	1	1
Fuel	8	7	7
All other, incl. small tools	12	12	12
Materials	**504**	**493**	**495**
Metal products	*190*	*328*	*304*
Bolts, nuts, washers, rivets	1	1	1
Castings, iron and steel	2	10	9
Forgings, iron and steel	1	§	§
Hardware	1	§	§
Hydrants and valves	36	36	36
Lead	1	3	3
Metal doors, windows, frame, trim	5	1	2
Pipe and fittings	57	223	195
Cast iron	39	161	141
Wrought iron and steel	17	53	47
Copper and other nonferrous metals	1	8	7
Plumbing fixtures and supplies, excl. pipe	7	1	2
Sheet metal	4	§	1
Steel, reinforcing	59	9	18
Steel, structural	7	2	3
Tanks and towers	3	37	31
Wire and wireworks products	1	§	§
Metal products‖	7	4	5

(*Continued on page 14*)

(Continued from page 12)

Construction Expenditures for New Water Supplies—Continued

Item	Expenditures		
	Treatment Plant	Distribution System†	Weighted Total‡
	$1 million units		
Machinery and equipment	*151*	*37*	*56*
Electrical equipment (motors, generators, apparatus)	9	6	6
Electrical wiring and fixtures	27	3	7
Elevators and elevator equipment	6	0	1
Heating and ventilating equipment	10	2	3
Pumps and pumping equip. (incl. prime movers)	17	11	12
Water meters, regulators, gages	20	12	13
Water softening and treatment equipment	43	3	9
Foundry and machine shop products‖	19	1	4
Stone, clay, and glass products	*134*	*105*	*110*
Brick and hollow tile	12	5	6
Cement	7	2	3
Cement asbestos pipe	1	60	50
Clay pipe	2	1	1
Concrete pipe	3	18	15
Concrete, premixed	92	15	28
Marble, granite, slate	4	1	1
Sand, gravel, crushed stone	11	2	4
Stone, clay, glass products‖	4	1	2
Lumber products	*13*	*6*	*7*
Other materials	*16*	*18*	*18*
Expansion joints (hemp, jute, and other joint compounds)	3	3	3
Paints and varnishes	2	1	1
Paving materials and mixtures	2	12	10
Roofing materials	3	1	1
Rubber products	§	1	1
Materials‖	6	1	2
Total#	**1,000**	**1,000**	**1,000**

* The Bureau of Labor Statistics prepared the questionnaire and tabulated the returns in this survey, which is part of a study of interindustry flows of commodities and services being conducted by the BLS for the Department of Defense. Public Health Service engineers selected a sample of 200 representative water supply and sewage disposal systems constructed in 1948, 1949, and 1950, and, operating from 10 USPHS regional offices throughout the country, secured the necessary data from constructing engineers.

Although the sampling methods limit the reliability of the survey results, it is believed that these data will be valuable to analysts concerned with this type of construction. The only other similar data known to be available are for 1940 and cover Public Works Administration projects analyzed by the BLS.

† The sample analyzed included a few projects for which the treatment plants could not be segregated. Such projects are included in this category.

‡ An expenditures distribution for all water supply systems was derived by combining the separate sample data for treatment plants and distribution, or collection works, using as weights the aggregate 1948 contract awards for these types of projects, rather than the proportions represented by the sample contract values.

§ Less than $500. Sum combined with amount for the "not elsewhere classified" items.

‖ Not elsewhere classified.

\# The sum of the components may not equal totals because of rounding.

(Continued on page 16)

(*Continued from page 14*)

Information on water quality standards is being consolidated to aid water pollution control agencies, in a project which is being undertaken by Jack E. McKee, associate professor of sanitary engineering, for the California Institute of Technology. The work is being done under contract for the California Water Pollution Control Board.

Algae trouble may soon be worth cultivating if the work of Dr. Paul M. Cook, chemical engineer of the Stanford (Calif.) Research Institute, is brought to a successful conclusion. Looking ahead to the day when the earth's croplands no longer can support a greatly increased population, Dr. Cook has been attempting to develop a practical continuous process for the large-scale culture of algae to augment the world's supply of proteins and fats. And now that his recent experiments have eliminated most of the speculation formerly surrounding algae culture, water works men may look ahead to a day when they will be able to cater not only to man's thirst but to his appetite as well. And with various combinations of "proteins and fat" selling these days for up to $1.50 per lb., who knows but what the byproduct of water storage may outearn the product? With that thought in mind, let up hope no one spoils Dr. Cook's proposed broth.

(*Continued on page 68*)

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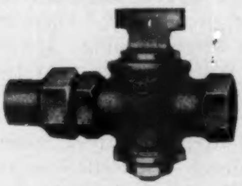
Hays Corporation Stop with inlet A. W. W. A. standard thread.

CATALOG No. 5622
Hays Tee for copper to copper to copper connection.



CATALOG No. 5050
Hays Curb Stop for iron pipe to copper service connection.

HAYS Manufacturing Company is one of the largest making a complete line of water service products, and for 80 years has enjoyed the prestige earned by unremitting insistence upon high quality. The HAYS line of fittings and other products is famous throughout the world for easy installation and a long life of trouble-free service.

All HAYS water works fittings are interchangeable with those of other manufacturers and corporation stops can be installed with any standard tapping machine equipment. They are made of highest quality 85-5-5-5 bronze, plugs are ground for perfect fit, specially lubricated for permanent easy turning, and hydrostatically tested at 200 pounds or more. Write for the new HAYS catalog showing the complete HAYS line of water works products.

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Hays Elbow for Male Iron pipe to copper connection.

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Hays Coupling for Male Iron pipe to copper connection.

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WATER WORKS PRODUCTS
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Correspondence

Doubter to Dowser

To the Editor:

I note that recent issues of your section of the JOURNAL have devoted some space to "dowsing" or water witching, a questioned method of locating underground source of water.

A few years ago I was inspecting the well field of a rather large utility in company with the manager, an engineer. With a slight appearance of embarrassment, he asked if I knew anything about water witching. I replied that I had heard about it many times but never witnessed a demonstration. Walking over to the river rank, he cut a small willow crotch or fork, trimmed it and, holding it in a vertical position, started walking. Soon the crotch started to move to a horizontal position. Continuing the walk for a short distance, the vertical position was restored.

Now that was something; so I asked if I could try. Holding the crotch in the approved position, with the palms up, thumbs out and the ends of the crotch pointing outward I started walking.

Now if there was ever a doubting Thomas, one had hold of that piece of willow branch. So help me, when I approached a certain spot the crotch started down and at one spot moved a full 90 degrees from the vertical to the horizontal. Further walking restored the vertical position. Going to

(*Continued on page 20*)

(*Continued from page 18*)

another part of the field I walked across my original path crossing the line at the point of previous indication, with the same result.

Now don't ask me why this thing happened but I had such a firm grip on that twig that it had to bend or break, yet the movement from vertical took place, as firm and complete as if a second person had placed a finger on the top of the fork and bent it down to a level position.

What was under the indicated point? I did not dig to see—the wells in that field being from 600 to 1,150 feet deep—but that willow crotch *did move.*

My companion remarked that the thing "sure works for you" and incidentally stated that he had located a number of irrigation wells by this method and never had a dry hole.

The original Thomas had to be shown; I also.

R. G. Yaxley

Supt., Water Comrs.
Waterford, N.Y.; June 13, 1951

Witch kind of Thomas are you?—Ed.

On the Up and Up

To the Editor:

No doubt this has been brought to your attention, but I can't pass by the opportunity to tease you a little bit about the notation in the April issue of the Journal under Percolation and Runoff, Item No. 1, which comments that the new offices of the American Water Works Association are on the

(*Continued on page 22*)

(*Continued from page 20*)

39th floor of a 38-story building. I am really interested in knowing just what kind of a penthouse arrangement you have there and would like to get some information on the quantity of water used to irrigate your penthouse gardens. Perhaps one of your staff can write a dissertation for a coming issue of the JOURNAL of the advantages of fresh air offices located on the roof.

GERALD E. ARNOLD
Director, Water Department
702 Civic Center
San Diego 1, Calif.; May 23, 1951

For skeptical Gerry as well as any silently confused readers of our P&R claim, we ought to explain that we really are pent up. Of course, there's no unlucky 13th floor in the building, so that drops us a peg, but since we have space on the 40th floor as well, we'll not dodge the issue. This is a penthouse inasmuch as it's located one floor above the last elevator stop and the last conventionally countable story. Since the building was erected some 25 years ago, the space has had two other tenants. First was photographer Margaret Bourke-White, who had her studios here, with a 22-ft. ceiling throughout. Then came Trans-Radio News, who put in a balcony 40th floor. And now A.W.W.A.

To be specific, above our 40th floor, there is still more tower, which we can climb to reach a roof terrace or even further up, a water tank. The air we find is fresher here and cleaner, the view beautiful, and the water, over our heads. Besides, making you climb lets us pay less rent.

Our invitation still stands: Come up and see us sometime!

FOUR MORE DE LAVALS* for Philadelphia

This De Laval pump is one of four recently installed at the Fox Chase Booster Station. It is one of 36 De Laval pumping units serving the City of Philadelphia.

***80% of America's large cities use De Laval pumps.** WW-13

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TURBINES • HELICAL GEARS • CENTRIFUGAL BLOWERS & COMPRESSORS
CENTRIFUGAL PUMPS • WORM GEAR SPEED REDUCERS • IMO OIL PUMPS

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Membership Changes

NEW MEMBERS

Applications received May 1 to May 31, 1951

Adams, Howard Leslie, 750 N.W. 146th St., Miami 38, Fla. (Apr. '51) *M*

Alderwood Water Dist., Merna Keep, Supt., Alderwood Manor, Wash. (Corp. M. Apr. '51)

Baker, Hugh L., Vice-Pres., Mueller Co., Decatur, Ill. (Apr. '51)

Bartolo, Adolphe M., Asst. Chem. Engr., Southdown Sugars Inc., Southdown Plantantion, Houma, La. (Jr. M. Apr. '51) *MP*

Benson, Donald Hurley, Constr. Supt., B & M Construction Co., 315 Petroleum Bldg., Oklahoma City, Okla. (Apr. '51) *R*

Blong, W. J., *see* Fox Point

Bogush, Simeon, San. Chemist, Filtration Plant, Water Works Park, Detroit 14, Mich. (Apr. '51) *P*

Bracken, Elmer F., *see* South Norwalk (Conn.) Second Dist. Water Dept.

Brown, I. F., Water & Sewer Supt., Box 547, Williams, Ariz. (Apr. '51) *MP*

Bryan, James R., Director of Public Works, McKinney, Tex. (Apr. '51) *M*

Buker, Harry William, Town Mgr., Princess Anne, Md. (Apr. '51) *M*

Calleja, Gustavo, Pres., Corporacion General de Ingenieria S.A., Morro 158, Havana, Cuba (Apr. '51) *MPR*

Cederwall, Roy, Pacific Sales Co., 543—1st Ave., S., Seattle, Wash. (Apr. '51)

Coleman, Richard D., Jr. Asst. San. Engr., U.S. Public Health Service, CDC Activities, State Dept. of Public Health, 760 Market St., San Francisco 2, Calif. (Apr. '51) *P*

Collins, Guy C., Lime Plant Foreman, Dept. of Water & Sewers, Miami, Fla. (Apr. '51) *P*

Connelly, Edward M., Owner, Culligan Soft Water Service of Richfield, 4126 Cedar Ave., Minneapolis, Minn. (Apr. '51) *P*

Cromwell, Clyde E., Sales Mgr., Commercial Div., DeLaval Steam Turbine Co., Trenton, N.J. (Apr. '51)

Cullum, George P., Sr., Partner, W. G. Cullum & Co., 502 Great National Life Bldg., Dallas 1, Tex. (Apr. '51)

Davis, Rudolph, Salesman, Davis Meter Repair & Supply Co., Thomasville, Ga. (Apr. '51)

Day, Robert V., Research Chemist, Wallace & Tiernan Co., Inc., Belleville, N. J. (Apr. '51) *P*

Deming, J. E., *see* Elizabethtown (N.Y.) Water Co.

Denise, William D., Monroe County Water Authority, 486 Demise Rd., Rochester 16, N.Y. (Apr. '51)

De Puy, Emerson, Sales Engr., 679 First National Bank Bldg., Chicago 3, Ill. (Apr. '51)

Dixon, L. A., Jr., Asst. Vice-Pres., Meter & Valve Div., Rockwell Manufacturing Co., Pittsburgh, Pa. (Apr. '51) *MPR*

Donovan, Terrence H., Exec. Officer State of California Colorado River Basin Water Pollution Control Board, 82—454 Miles Ave., Indio, Calif. (Apr. '51) *R*

Drumb, Elmo Clifton, City Engr., Denison, Tex. (Apr. '51) *M*

Elizabethtown Water Co., J. E. Deming, Secy.-Treas. & Supt., Elizabethtown, N.Y. (Corp. M. Apr. '51) *M*

Everett, C. H., Pres. Calude Everett Inc., Box 500, Houston 1, Tex. (Apr. '51)

Eynon, George F., Asst. Div. Mgr., Municipal Management Co., 121 S. Broad St., Philadelphia 7, Pa. (Apr. '51)

Ferdinand Water Works, Erwin Schafer, Supt., Munic. Light & Power Plant, Ferdinand, Ind. (Corp. M. Apr. '51) *MPR*

Floyd, Charles, Jr., Sales Engr., Badger Meter Mfg. Co., Box 1897, Greenville, S.C. (Apr. '51)

(*Continued on page 32*)

(Continued from page 30)

Foley, Joseph, Water Consultant, E. I. du Pont de Nemours & Co., Wilmington 98, Del. (Apr. '51) *PR*

Fox Point, Village of, W. J. Blong, Village Engr., 8340 N. Lake Dr., Milwaukee 11, Wis. (Mun. Sv. Sub. Apr. '51)

Gordier, Robert Loro, Student, Univ. of Minnesota, Minneapolis 14, Minn. (Jr. M. Apr. '51)

Haestad, Roald J., Clinton L. Bogert Assocs., 624 Madison Ave., New York, N.Y. (Apr. '51)

Hart, Virgil S., Water Supt., Elma, Wash. (Apr. '51) *MPR*

Heldenfels, F. W., Jr., Partner, Heldenfels Bros., Box 1917, Corpus Christi, Tex. (Apr. '51)

Holmes, D. Max, Inspector, Water Project, Box 682, Hallandale, Fla. (Apr. '51)

Homestead Water Works, Gordon W. Ivey, Supt. of Utilities, 940 N.W. 1st Ave., Homestead, Fla. (Mun. Sv. Sub. Apr. '51) *M*

Ivey, Gordon W., *see* Homestead (Fla.) Water Works

Johnson, Frank W., Asst. Supt., Water Dept., City Hall, The Dalles, Ore. (Apr. '51) *MP*

Keep, Merna, *see* Alderwood (Wash.) Water Dist.

Kilkenny, T. D., *see* Vallejo (Calif.)

Kinneally, James J., Secy. & Acting Supt., Board of Water Comrs., City Hall, Rahway, N.J. (Apr. '51)

Koether, Reuben H., City Mgr. & Mgr. of Utilities, 703 West St., Yoakum, Tex. (Apr. '51) *MPR*

Kubala, John, Water Supt., West, Tex. (Apr. '51)

Laffey, William T., Field Engr., Infilco Inc., 2188 B Daisy Lane, Schenectady 9, N.Y. (Apr. '51) *P*

Lakeland Light & Water Dept., Charles Larsen, Supt., Box 480, Lakeland, Fla. (Corp. M. Apr. '51) *M*

Larsen, Charles, *see* Lakeland (Fla.) Light & Water Dept.

Leamington Public Utilities Com., A. C. Northover, Mgr., Leamington, Ont. (Corp. M. Apr. '51)

Lefler, W. A., Owner, Lefler Wyomont Supply Co., 234 Stapleton Bldg., Billings, Mont. (Apr. '51) *P*

Leuckel, Carl N., Water Supt., 215 Doerr St., Perryville, Mo. (Apr. '51)

Lundberg, Herman Frederick, Cons. Engr.-Partner, The Chester Engrs., 210 E. Parkway, Pittsburgh 12, Pa. (Apr. '51) *MPR*

Marsh, Elmo L., City Engr., Box 891, Shelby, Mont. (Apr. '51) *M*

McArtor, W. P., Inspector, J. B. Wilson, Indianapolis, Ind. (Apr. '51)

McGraudy, Grant Logan, Pumping Plant Operator, Southern California Water Co., 1206 S. Maple, Los Angeles, Calif. (Apr. '51) *MP*

McNeal, Francis E. J., Asst. Civ. Engr., Water Dept., 215 W. Broadway, Long Beach, Calif. (Apr. '51) *M*

Miller, G. G., Branch Mgr., E. S. Stephenson & Co., Ltd., 155 Granville St., Halifax, N.S. (Apr. '51)

Morkus, Vincent A., Chemist & Bacteriologist, Metropolitan Dist. Water Bureau, 115 Broad St., Hartford, Conn. (Apr. '51)

Morris, Robert L., Prin. Water Analyst, State Hygienic Lab., SUI, Iowa City, Iowa (Apr. '51) *P*

Noll, Dean C., Engr., North Jersey Dist. Water Supply Com., Wanaque, N.J. (Jr. M. Apr. '51)

Northover, A. C., *see* Leamington (Ont.) Public Utilities Com.

Obert, L. R., Mgr., Santa Fe Tank & Tower Co., 5401 S. Boyle Ave., Los Angeles 58, Calif. (Apr. '51)

O'Donnell, John R., Owner, J. R. O'Donnell & Co., 1070 Bryant St., San Francisco, Calif. (Apr. '51)

Paragon Munic. Water Works, O. E. Shuler, Paragon, Ind. (Corp. M. July '51)

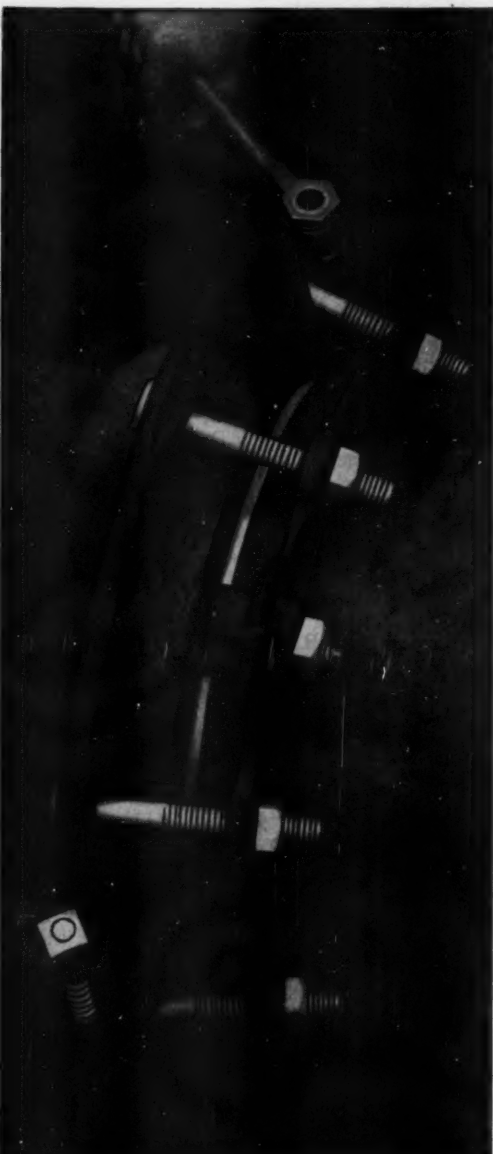
Parker, William W., Supt., Water Works, Mackinaw City, Mich. (Apr. '51) *M*

Plowman, Herbert L., Secy., Gary-Hobart Water Corp., 545 Broadway, Gary, Ind. (Apr. '51) *M*

Puro-Filter Corp., Richard A. Sloss, Secy., 21-01—51st Ave., Long Island City, N.Y. (Corp. M. Apr. '51)

Rademacher, John Martin, Sales & Service Engr., Wallace & Tiernan Co., 230 E. Ohio, Indianapolis 5, Ind. (Apr. '51) *MP*

(Continued on page 34)



(*Continued from page 32*)

Rogers, Edgar M., Salesman, General Chemical Div., Box 970, Charlotte, N.C. (Apr. '51) *P*

Russell, Conrad F., *see* Weatherford (Tex.)

Schaefer, Edward W., Public Health Engr., U.S. Public Health Service, Red Cross Bldg., 417 E. 13th St., Kansas City 6, Mo. (Apr. '51)

Schafer, Erwin, *see* Ferdinand (Ind.)

Shehadi, Fawzi Ibrahim, San. Engr., Ministry of Public Health, American Univ., Beirut, Lebanon (Apr. '51) *MR*

Shuler, O. E., *see* Paragon (Ind.)

Sirola, Oliver J., Supervisor, Water Dept., Painesville, Ohio (Apr. '51) *M*

Slaby, Francis J., Graduate Student, Johns Hopkins Univ., Baltimore 18, Md. (Apr. '51) *R*

Sloan, Odes, Water Supt., & Sewer Engr., City Hall, 4 E. Kennewick Ave., Kennewick, Wash. (Apr. '51) *M*

Sloss, Richard A., *see* Puro-Filter Corp.

Snider, Harold R., Supt., Munic. Water Utility, Morgantown, Ind. (Apr. '51)

South Norwalk Second Dist. Water Dept., Elmer F. Bracken, Gen. Mgr., City Hall, N. Main St., South Norwalk, Conn. (Corp. M. Apr. '51)

Steed, Brandon E., Pipe Salesman, Johns-Manville Sales Corp., 917 State Planters Bank Bldg., Main & 9th Sts., Richmond, Va. (Apr. '51) *M*

Stephenson, A. E., Pres., E. S. Stephenson & Co., Ltd., 15 Dock St., St. John, N.B. (Apr. '51)

Stoertz, Robert W., Control Lab. Director, West Virginia Pulp & Paper Co., Charleston, A, S.C. (Apr. '51) *P*

Suarez, Doyle J., Jr., Asst. Secy., The Baton Rouge Water Works Co., Drawer 2391, Baton Rouge, La. (Apr. '51) *M*

Swisher, A. Dale, San. Engr., Engr. Section, Hdq. & Service Command, GHQ, FEC, APO 500, c/o Postmaster, San Francisco, Calif. (Apr. '51)

Symons, E. A. C., Chief Engr., Public Utilities Com., 19 Queen St., Kingston, Ont. (Apr. '51)

Trueheart, J. C., Owner, J. C. Trueheart, 812 Insurance Bldg., San Antonio, Tex. (Apr. '51)

Vallejo, City of, T. D. Kilkenny, City Engr., Room 4, City Hall, Vallejo, Calif. (Corp. M. Apr. '51) *MPR*

Van Wambeke, Ned, Salesman, Waterous Co., 80 E. Fillmore, St. Paul 1, Minn. (Apr. '51)

Vexler, Nathaniel, Sr. Engr., Elec. Branch, Mech. Dept., Mekoroth Water Co., Ltd., 111 Allenby Rd., Tel Aviv, Israel (Apr. '51) *MP*

Vry, D. C., Layne-Minnesota Co., Box 347, Billings, Mont. (Apr. '51) *PR*

Weatherford Munic. Water & Elec. Dept., Conrad F. Russell, Mgr., 201 Palo Pinto St., Weatherford, Tex. (Corp. M. Apr. '51) *MR*

Wells, K. R., Canadian Branch Mgr., George Kent Ltd., Royal Bank Bldg., Toronto 1, Ont. (Apr. '51)

Willard, Harry E., Water Service Inspector, Water Dept., 323 County-City Bldg., Seattle, Wash. (Apr. '51)

Williams, Charles W., Mgr., Fordyce Water Co., Box 620, Fordyce, Ark. (Apr. '51) *M*

Zody, Carl T., Gen. Supt., C & C Construction Co., 2001 E. Pontiac St., Fort Wayne, Ind. (Apr. '51)

REINSTATEMENTS

Biddle, Earl W., 2 Lenox Ave., Cranford, N.J. (Oct. '37)

Campion, Harry T., San. Engr., State Dept. of Health, First National Bank Bldg., Greensburg, Pa. (Apr. '44) *P*

Gaboury, Maurice, San. Eng. Div., Ministry of Health, 1570 St.-Hubert St., Montreal 24, Que. (Jan. '34)

Jenne, Lyle L., San. Engr., Bureau of Water, 825 City Hall Annex, Philadelphia 7, Pa. (June '21) *MPR*

Kenney, Don, Foreman, Water Dept., 305 S. Oak St., McPherson, Kan. (Jan. '49)

Smith, Doyle, Water Supt., Box 3, Hobart, Okla. (Jan. '49)

Whiddon, Edwin L., Supt. of Water Dept., Bellaire, Tex. (Oct. '46) *M*

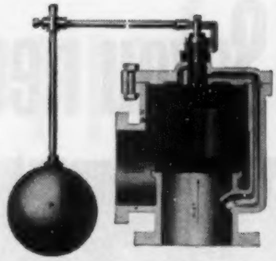
White, Hardin, Supt., Water & Sewage, Altus, Okla. (Jan. '49)

LOSSES

Deaths

Geisinger, G. L., Cons. Engr., 122 Elliott Ave., W., Seattle 99, Wash. (Jan. '49) *P*

(*Continued on page 38*)



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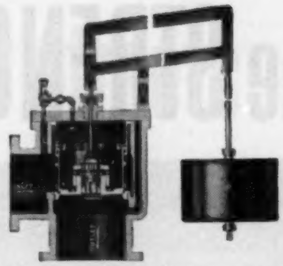

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(*Continued from page 34*)

Morgan, Robert M., Director of Water, City Bldg., Fairmont, W. VA. (Jan. '49) *MP*

Moses, D. V., Tech. Supt., Ammonia Dept., E. I. du Pont de Nemours & Co., Belle, W.Va. (July '39)

Schmid, E. B., Schuyler, Neb. (July '46) *M*

Scoular, Spencer Gray, City Engr., Dunedin City Corp. of New Zealand, Town Hall, Dunedin, C.I., New Zealand (Jan. '39)

Resignations

Ayliffe, Ora C., Supt., Water Works, 1429—7th St., S., Fargo, N.D. (July '37)

Chamblee, Graham V., Forest Mgr., Newport News Water Works Com., Denbigh, Va. (Jan. '47) *R*

English, Wayne, Local Mgr., Hoosier Water Co., Bloomfield, Ind. (Oct. '50)

Erwin, Raymond A., Elec. Engr., Los Angeles Dept. of Water & Power, 410 Ducommun St., Los Angeles 12, Calif. (Jan. '47) *M*

Grant, Walter Schuyler, Jr., Chief Engr., Water Works Com., Newport News, Va. (Oct. '49) *MPR*

Hamilton, S. C., Dist. Sales Mgr., Chicago Bridge & Iron Co., 1412 National Standard Bldg., Houston 2, Tex. (Jan. '36) *P*

Hartford Rayon Corp., O. W. McLane, Supt., Rocky Hill, Conn. (Corp. M. Oct. '48)

Hickcox, R. M., Water Supt., Water Shop, Wenatchee, Wash. (Apr. '38)

Huffman, H. H., Supt., Water & Street Lighting Dept., Topeka, Kan. (Jan. '32)

Jacoby, Gordon C., Jacoby, McGrayne & Co., Cons. Engrs., 8 Essex St., Hackensack, N.J. (Oct. '46)

Kilgour, Ross G., Mgr., Crescenta Mutual Water Co., 2012 Montrose Ave., Montrose, Calif. (Oct. '48)

Moore, Herbert, Hydr. & San. Engr., 1330 N. Franklin Pl., Milwaukee 2, Wis. (July '28) *MPR*

Rippey, George S., Mech. Engr., 1823 S. Delaney St., Orlando, Fla. (Jan. '47)

Teckoe, John Edward, Jr., Gen. Mgr., Public Utilities Com., 62 Dickson St., Galt, Ont. (Apr. '47) *MR*

Washburn, Edward A., Mgr., Public Utilities Com., Ingersol, Ont. (Apr. '48)

CHANGES IN ADDRESS

Changes received between May 5 and June 5, 1951

Alexander, Aleck, 2715 Jefferson St., Boise, Idaho (July '48)

Alexandria Water Dept., R. L. Lawrence, Chemist, City Hall, Alexandria, La. (Corp. M. Jan. '43) *P*

Allen, Victor H., 94 Hastings Avenue, Croton-on-Hudson, N.Y. (Jan. '39)

Bird-Archer Co., H. C. Stevens, Tech. Director, 4337 N. American St., Philadelphia 40, Pa. (Assoc. M. July '29)

Blackburn, Schuyler Coe, Deputy Director of Civil Defense, 3303 Frisby St., Baltimore 18, Md. (Jan. '42) *M*

Blais, Marcel, 206 Manseau St., St. Joseph, Que. (Oct. '49)

Brinck, Claiborne W., Director, Div. Environmental San., State Board of Health, Helena, Mont. (Jan. '43)

Cary, E. S., 130 Highland St., Evansville, Wis. (Oct. '35)

Cissna, George W., Southwest Mgr., Neptune Meter Co., 315 Cole St., Dallas 2, Tex. (July '35)

Crane, Harlan B., Civ. Engr.-Repr., Infilco Inc., 2145 Route 4, Fort Lee, N.J. (July '43) *P*

Crawford, Lawrence C., Dist. Engr., U.S. Geological Survey, 1509 Hess St., Columbus 12, Ohio (Jan. '47) *R*

Gomez Laurens, Gilberto, Calle 18 No. 8-35, Bogota, Colombia (Jr. M. Oct. '49)

Green, Carl E., Cons. Engr., Carl E. Green & Assocs., 510 Henry Bldg., Portland 4, Ore. (July '31) *MPR*

Halpin, David J., 2301 Pemberton Dr., Toledo 5, Ohio (Jr. M. Oct. '50)

Hazen, Richard, Cons. Engr., 110 E. 42nd St., New York 17, N.Y. (July '37) *PR*

Henderson, William Bartow, Statistician & Records Clerk, Water Dept., 510 Opa Locka Blvd., Miami 38, Fla. (Oct. '50)

Herring, R. S., *see* Kamloops (B.C.)

Jens, Stiffel W., 101 S. Meramec Ave., St. Louis 5, Mo. (Jan. '44) *R*

(*Continued on page 40*)

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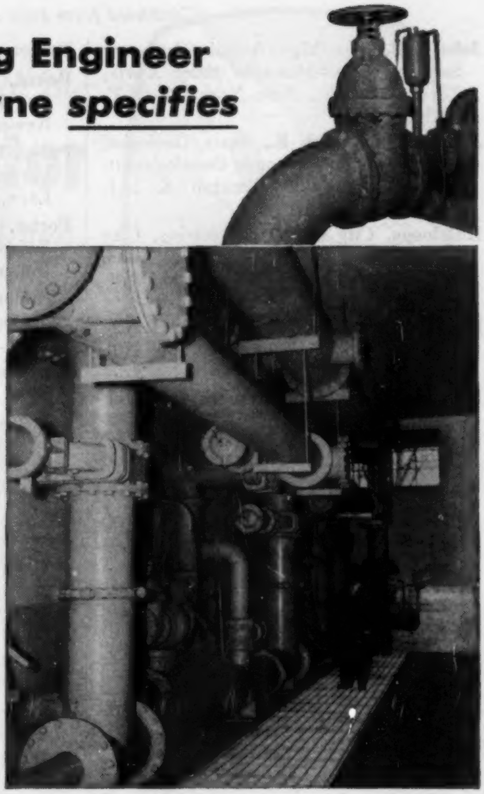

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Jobe, J. B., Asst. Mgr., Aviation Industry Section, Johns-Manville Sales Corp., 22 E. 40th St., New York 16, N.Y. (July '48)

Johnson, Meredith E., State Geologist, Dept. Cons. & Economic Development, 520 E. State St., Trenton 8, N.J. (Affil. July '38) *R*

Kamloops, City of, R. S. Herring, City Engr., Water Works Dept., 112 Lorne St., Kamloops, B.C. (Corp. M. Apr. '44) *M*

Kelso, Gilbert L., School of Public Health, Univ. of North Carolina, Chapel Hill, N.C. (May '30) *P*

Kendrick, R. A., *see* New Mexico, University of

Kingston Public Utilities Com., F. J. Parker, Gen. Mgr., 19 Queen St., Kingston, Ont. (Corp. M. July '41) *MP*

Kolkowitz, Hyman, 13824 Oxnard St., Van Nuys, Calif. (Oct. '48) *PR*

Koon, Ray Emerson, Stevens & Koon, Cons. Engrs., 404 S.E. 68th Ave., Portland 16, Ore. (Feb. '22)

Krell, A. J., 6412 Rutgers, Houston 5, Tex. (Apr. '39) *MPR*

Lalonde, J. A., Cons. Engr., 7379 St. Hubert St., Montreal 10, Que. (Apr. '47)

Lawrence, R. L., *see* Alexandria (La.)

Lemieux, Pierre, City Chemist, Water Purif., 121 Berard St., Drummondville, Que. (Oct. '50)

Limbaugh, James E., Box 766, Fostoria, Ohio (Jan. '51)

MacLean, Gordon E., Sales & Service, Dearborn Chemical Co., 918 Brownlee Rd., Memphis 16, Tenn. (Oct. '49)

Martin, H. Fred, 24 California St., San Francisco 11, Calif. (Jan. '46) *MPR*

Mayfield, David A., Jr., Secy.-Treas., Mayfield & Son Co., 131 E. Bay St., Jacksonville 2, Fla. (Jan. '51) *P*

McKim, Township of, Frank Totino, Engr., 11 Elm St., E., Sudbury, Ont. (Corp. M. Jan. '51)

New Mexico, University of, R. A. Kendrick, Acting Supt., of Utilities, Utility Dept., Albuquerque, N.M. (Corp. M. Oct. '47) *M*

Ongerth, Henry J., Sr. San. Engr., Bureau of San. Eng., 1843 Berryman St., Berkeley 3, Calif. (Oct. '39) *P*

Parker, F. J., *see* Kingston (Ont.)

Peirce, Millard O., Jr., Peirce-Tredinick Co., Inc., 202–204 Frelinghuysen Ave., Newark 5, N.J. (July '48) *R*

Perry, Robert E., Sales & Service Engr., Wallace & Tiernan Co., Inc., 117 Wade Lane, Oak Ridge, Tenn. (July '50)

Porter, Earl, Partner, Porter, Barry & Switzer, Cons. Engrs., Box 1667, Baton Rouge, La. (Jan. '49) *P*

Richmond, Maurice S., Asst. Engr., Div. of Eng., State Dept. of Health, Lansing, Mich. (Jan. '49)

Rinehart, Ray G., Sales Engr., James B. Clow & Sons, 202 Timber Lane, South Bend, Ind. (Apr. '48)

Robbins Mills, Inc., V. T. Fahringer, Chief Engr., Clarksville Finishing Div., Clarksville, Va. (Corp. M. July '49) *MPR*

Robinson, T. C., City Engr., City Hall, Georgetown, S.C. (July '38)

Runyan, Marvin W., Design Engr., Stevens & Koon, 732 S.W. 3rd Ave., Portland 4, Ore. (Jan. '51)

Stevens, H. C., *see* Bird-Archer Co.

Stone, Raymond V., Jr., Research San. Engr., Univ. of California, Richmond Field Station, 1301 S. 46th St., Richmond 4, Calif. (Apr. '50)

Talcott, George R., R. Stuart Royer & Assocs., 401 Virginia Bldg., Richmond, Va. (Jan. '46)

Taylor, Orville W., 924 Park Ave., Dunbar, W. Va. (Oct. '46)

Thompson, H. Loren, Engr., Stevens & Koon, 732 S.W. 3rd Ave., Portland 4, Ore. (Jan. '46) *PR*

Tobin, David, Sales Engr., Jos. W. Eshelman & Co., Inc., 521 N. Church St., Charlotte 6, N.C. (Oct. '48)

Totino, Frank, *see* McKim

United Concrete Pipe Corp., Henry A. Weigand, Box 425, Baldwin Park, Calif. (Assoc. M. Apr. '48)

Valve & Primer Corp., F. H. Bradford, Pres., 356 W. Huron St., Chicago 10, Ill. (Assoc. M. Apr. '48)

Weigand, Henry A., *see* United Concrete Pipe Corp.

Wright, K. W., Sales Engr., Jos. W. Enshelman & Co., Inc., 521 N. Church St., Charlotte 6, N.C. (Apr. '49)

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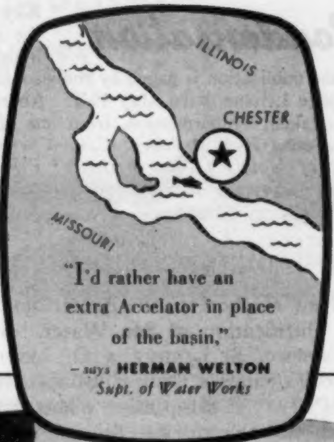

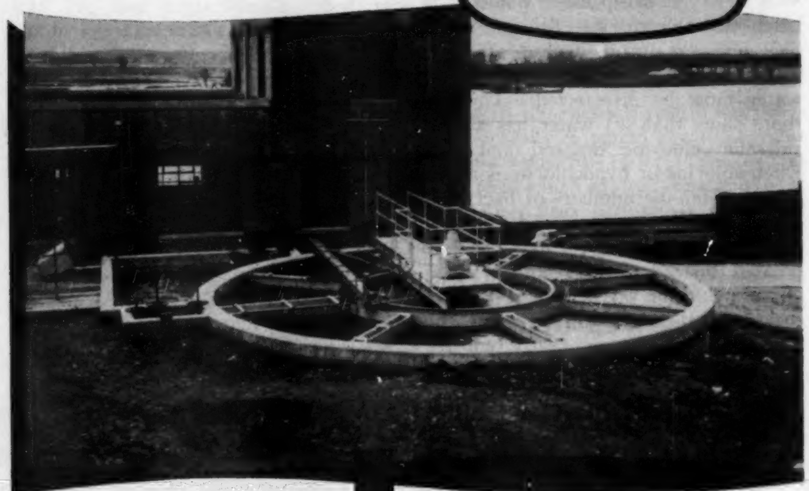

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DISINFECTION

A New Method for the Bacteriological Purification of Sea Water. M. Lundborg, S. Lindhe & O. Levin. Handl. Chalmers Tekn. Högskolas No. 99 ('50). At fish-packing plants it is often desirable to rinse fish and shellfish with sea water instead of fresh water, and for this purpose the sea water must be disinfected. The authors show that sea water has a considerable chlorine demand and that when chlorine or hypochlorite is added to sea water the numbers of bact. that grow on gelatin, nutrient agar and dextrose-tryptone agar may be increased instead of decreased. When nascent chlorine was produced by electrolysis of the sea water, however, the numbers of bact. were greatly reduced. Apparatus used for electrolyzing sea water and the methods used for detg. chlorine are described. Results of chlorination by the various methods are given in tables.—*W.P.A.*

The Bactericidal Action of Ozone. R. H. Leiguarda, O. A. Peso & Ana Z. R. de Palazzolo. Rev. Obras. San. Nacion, **13**:132:33 ('49). The bactericidal action of ozone was investigated on suspensions of *Esch. coli* and *Cl. welchii* (vegetative forms and spores) in water to which buffer solns. had been added and which had been rendered free from ozone demand. Estns. of ozone made by the o-t. test or, if concns. were more than 0.5 ppm., by iodometry. Its disinfectant power was also tested on raw Plate R. water and in coagulated and decanted river water. From these tests it has been found that the action of ozone on *Esch. coli* suspensions is rapid. Doses of 0.12 ppm. of ozone produce a 100% kill within 5 min. contact, and doses of 0.22 ppm. achieve this in three min. or less. Temperature and pH had very little effect on the bactericidal action. Similar results were obtained with suspensions of vegetative cells of *Cl. welchii* in the buffered water solns., a dose of ozone of 0.12 ppm. being effective within 5 min. On the other hand with the spores of *Cl. welchii* doses of 3 ppm. were required to produce a 100% kill within 5 min. and 0.25 ppm. produced the same result within 15 min. Ozone had a greater effect on the spores than chlorine for it was found that, under similar exptl. conditions, 10 ppm. of chlorine were required to bring about total destruction of spores and even then this was not achieved with this dose until after 30 min. contact; 2 ppm. of chlorine failed to have any effect at all after 1 hour's contact. Larger doses of ozone were required to sterilize Plate R. water having a 24 hours' total plate count on agar at 37°C. of 10,000 per ml. It appears that the bactericidal action of the ozone proceeds *pari passu* with the oxidation of the ozone by the org. matter in the water (org. demand for ozone) and when a sufficient dose of ozone has been added to satisfy the whole of the demand, the water is found to be sterile. A dose of ozone of 6 ppm. sterilized the raw river water within 15 min. An expt. was also carried out with coagulated and decanted river water to which a dild.

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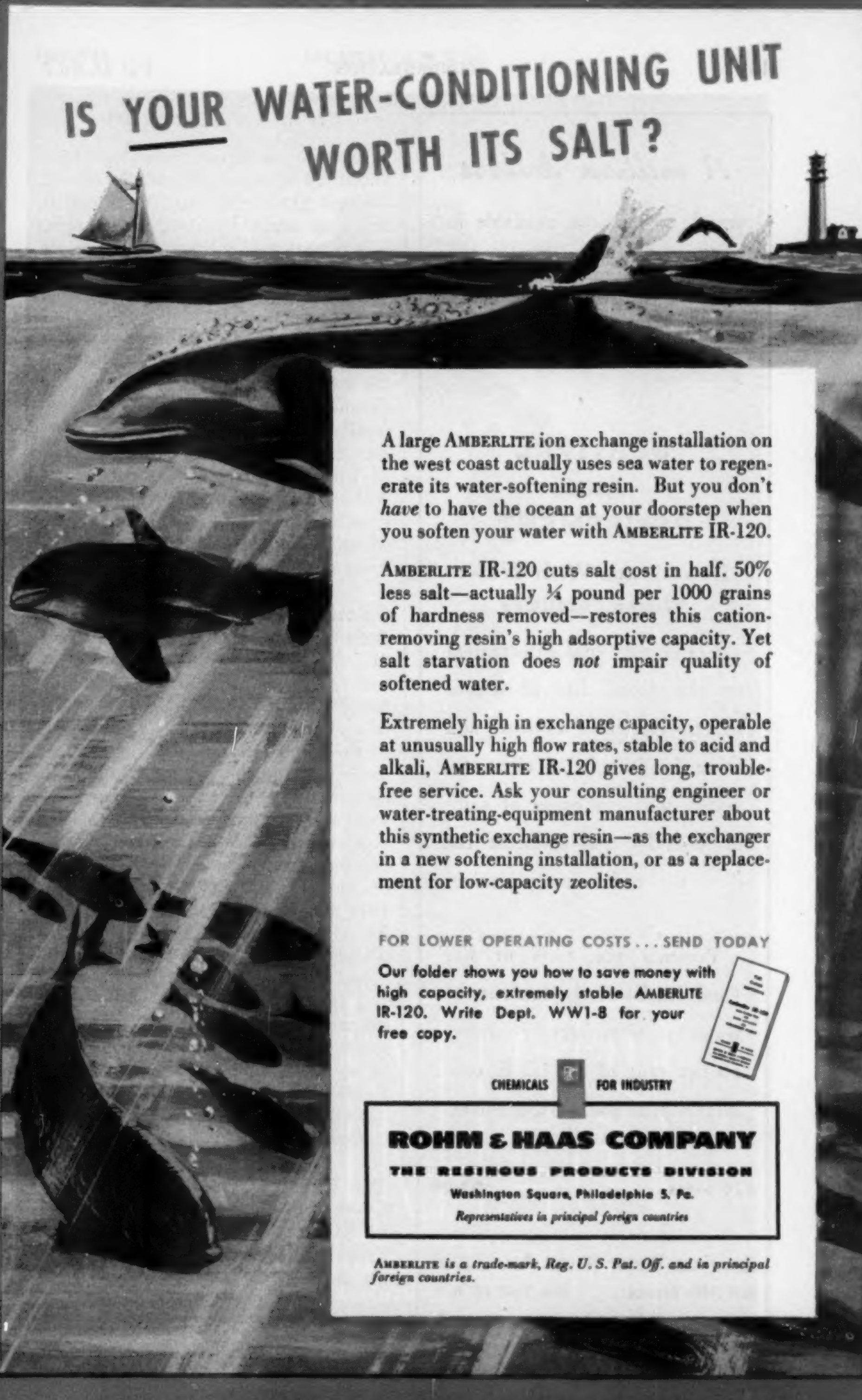
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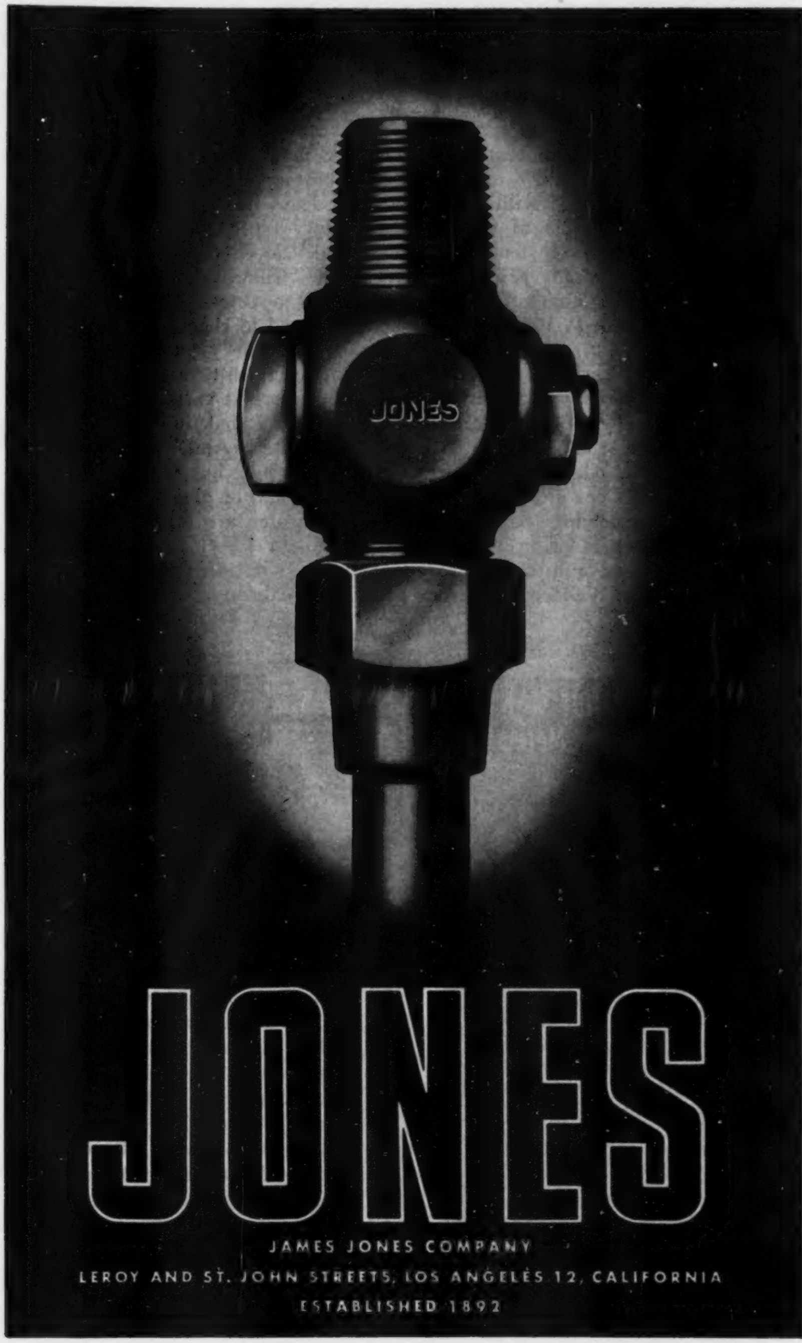
(*Continued from page 42*)

suspension of *Esch. coli* had been added. The water was finally filtered through glass wool and the effect of doses of ozone from 0.2 to 1.6 ppm. was investigated by making total plate counts at intervals after dosing. As with raw river water it was observed that the bactericidal action begins before any residual of ozone can be detected by the o-t. test and, by the time the ozone demand of the sample is satisfied, the water is sterile and the small quantity of ozone remaining persists for several min. A dose of ozone of 1.6 ppm. produced a sterile water within 2 min. and at the end of that time there was a residual of 0.16 ppm. of ozone, some of which persisted for more than 3 min.—*B.H.*

Chlorine Dioxide as a Bactericidal Agent. F. V. H. PIPER. Pub. Wks., **81**:1:46 ('50). When chlorination was used to disinfect the water supply for Niagara Falls, N.Y., tastes and odors developed. In 1944 treatment of the filtered water with chlorine dioxide was adopted in conjunction with chlorination before filtration, but there were still intermittent tastes and odors. Analyses of the water showed that odorous samples contained 0.05 ppm. or more free residual chlorine. In 1949 addn. of chlorine dioxide before filtration was adopted, followed after filtration by chlorination to give a residual content of, at first, 0.2 ppm., and later 0.15 ppm. A slight chlorinous taste was still present, so finally, as the chlorine dioxide had been shown to be an adequate disinfectant, chlorination was discontinued, and treatment with chlorine dioxide before filtration is now used alone.—*W.P.A.*

The Effect of Ozone in Water on Cysts of *Endamoeba histolytica*. W. L. NEWTON & M. F. JONES. Am. J. Trop. Med., **29**:669 ('49). Cysts of the NRS strain of *Endamoeba histo-*

(*Continued on page 46*)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(*Continued from page 44*)

lytica were exposed to varying concns. of ozone in aqueous soln. and the number of surviving cysts was estd. by the ability of the treated cysts to grow in a medium to which the NRS bact. flora has been added. Over 99% of the cysts exposed were killed within 1–3 minutes after applications of 0.5–1.0 ppm. ozone. Variations in temp. bet. 10° and 27°C. and in the pH range 6.5–8.0 did not appear to affect the action of the ozone.—W.P.A.

Operating Characteristics of the Timmermann "Chlorownica Górnośląska" Injector-Type Chlorination Apparatus. W. Hermanowicz & W. Dozanska. Gaz, Woda i Tech. Sanit. (Poland) **24**:425 (Dec. '50). Devices for chlorinating water may be divided into two classes depending on whether they operate at high or low pressure. First group includes Wallace and Tiernan, "Polska Chlorownica," Ornestein, Paterson, Paradon, Remieslnicki and similar units, and their main defect, according to authors, is that chlorine may escape and constitute a hazard to workmen in area. Second group does not have this defect. Laboratory studies were made on newly developed low-pressure Timmermann "Chlorownica Górnośląska" apparatus to determine its mode of operation and to check theoretical discussions previously submitted by authors of reactions taking place in unit. Reactions were at variance with those suggested by Rybak in earlier discussion of unit. [Authors present description of app. but description does not seem clear to abstractor.] Chlorine and water are mixed after passage through injectors and complete absorption (insofar as chem. anal. shows) of chlorine gas in water takes

(*Continued on page 48*)

(Continued from page 46)

place. Reaction shown to be $Cl_2 + H_2O \rightarrow HCl + HClO$. Operating characteristics are indicated and authors show apparatus discharged free chlorine at rates varying from 30 to 430 g./hr. at temp. of 5–7°C., which gives Cl_2 concn. of 30–1220 ppm. Studies revealed that discharge through chlorine meter too small relative to discharge of water and that it should be increased by a factor of 2 for low temps. by a factor of 3. Discharge of free chlorine in subsequent models should range from 400 to 1000 g./hr.—*C. P. Straub.*

Experimental Investigation of Factors Hindering the Disinfection of Water by Means of Chlorine. S. V. Moiseev. Gigiena (U.S.S.R.), **10**:22 ('49). Expts. are described which were made to investigate the mechanism of interference of org. substances with the bactericidal effect of chlorine in water. It was found that humic acids from various sources interfered with chlorination but that the extent of this interference varied with the source of the acid. In some expts. interference was not observed unless 10–100 ppm. of humic acid added to water, but addn. of 0.1 ppm. of humic acid from another source entirely prevented any bactericidal action of 0.3–0.5 ppm. of free chlorine even after a period of contact of 2 hr. It is suggested that the effect of these acids may be due to surface activity, and that a monomolecular layer is formed over the surface of the bact., thus preventing access of chlorine. Humic acids are also colloids, and in a neutral medium they are coagulated with calcium, aluminum or iron compds., forming flocs which trap the bact. and give them partial protection from the action of chlorine. Other substances which increase surface viscosity and which also hinder chlorination include peptone, hydrolysed casein, amino acids and waste waters from slaughter

(Continued on page 50)


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(*Continued from page 48*)

houses, meat-processing plants, tanneries, adhesives manufacture, lac-dyeing works, soap works, spinning and weaving mills, milk-processing, breweries and glue manufacture.—*W.P.A.*

Evaluation of the Antibacterial Efficiency of Dilute Solutions of Free Halogens. L. GERSHENFELD & B. WITLIN. J. Am. Pharm. Assn. **38**:411 ('49). A study has been made to compare the bactericidal efficiencies of dil. solns. of free bromine, free iodine and chlorine. Expts. were made in which 0.5 ml. of 24-hr. cultures of *Staphylococcus aureus, Sal. typhosa, Ps. aeruginosa, Esch. coli,* and vegetative forms of *B. megatherium, B. mesentericus,* and *B. subtilis* were exposed for varying periods at temps. of 24° and 37°C. to 5 ml. of solns. contg. the halogens in concns. of 0.02%. Results showed that within a period of 15 min. chlorine was ineffective against all species tested. Bromine was effective within 1 min. against *Staph. aureus, S. typhosa,* and *Esch. coli* at 24°C. and against *Staph. aureus* only at 37° C.; it was ineffective within 15 min. against the other species. Iodine was effective within 1 min. against all but *B. subtilis* and was ineffective against *B. subtilis* within 15 min. The effects of the presence of human plasma and the pH value on bactericidal efficiency were studied and results are given. In all tests iodine was more efficient than chlorine or bromine.—*W.P.A.*

Process and Apparatus for the Sterilization of Liquids. C. RONZI. *Swiss 256,237.* App. for the continuous disinfection of water by ozone comprises compressor unit, ozone generator and disinfecting chamber with a gas diffusion plate in the bottom and an atomizing and mixing nozzle in the top. This nozzle is so designed as to provide a rotating bell-shaped film of

(*Continued on page 52*)

(*Continued from page 50*)

liquid flowing down the walls of the chamber. Ozone is introduced through the sintered glass plate in the bottom and also with the water through the atomizing nozzle.—*W.P.A.*

Disinfection of Water. I. Free Iodine. K. Symon. Scr. Med. Fac. Med. Univ. Masaryk, **23**:1:1 ('49). The lethal effect of iodine on water microrganisms was investigated using aqueous solns. of iodine. Iodine has the same disinfecting effect as bromine and is 10 and 80,000 times more effective than chlorine and phenol respectively; the disinfectant action increases with decreasing pH value, decreases with increasing hardness of the water and is greatest at a temp. of 20°–30°C. The iodine number of the water should be detd. before a test is made as org. matter combines with some of the iodine and inactivates it.—*W.P.A.*

Evaluating the Bactericidal Efficiencies of Free Iodine and Available Chlorine by the "Semi-Micro" Method. L. Gershenfield & J. A. Palisi. Am. J. Pharm., **121**:337 ('49). The batericidal properties of iodine and chlorine were investigated, using Klarmann's "semi-micro" method in which 0.05 ml. of a 24-hr. culture of the test organism was placed in a test tube and mixed with 0.5 ml. of the disinfectant. After 10 min. sodium thiosulphate was added and 10 ml. of culture medium was poured into the tubes which were then incubated for 48 hr. at 37°C. A modification of the F.D.A. method was also used. Solns. with 2% available chlorine were prepared from 5% sodium hypochlorite. The iodine soln. was prepared from 2% tincture of iodine. With the "semi-micro" method, *Salmonella typhosa* was killed in 10 min. by a 1:4,000 soln. of available chlorine and by a 1:8,000 soln. of free iodine. *Staph. aureus* was killed in 10 min. by a 1:5,000 soln. of available chlorine and by a 1:6,000 soln. of free iodine. With the modified F.D.A. method, *S. typhosa* was killed in 10 min. by a 1:16,000 soln. of available chlorine and by a 1:12,000 soln. of free iodine. *Staph. aureus* was killed in 10 min. by a 1:12,000 soln. of available chlorine and by a 1:13,000 soln. of free iodine. —*W.P.A.*

The Necessity for Disinfection of Mineral Waters. H. Beger. Zbl. Bakt., I, Orig., Zbl. Bakt., I:**152**:333 ('48). The reasons for the fact that natural and artificial mineral waters are often of bad bact. qual. are discussed. Since the war the method used in Berlin for disinfecting mineral water has been to add 1,000 ppm. of "Micropur," a complex salt of silver

(*Continued on page 54*)

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and sodium chlorides, and 2,000 ppm. of an activating agent which keeps the reaction acid. Other methods, such as the Catadyn process, are discussed.—*W.P.A.*

Bacteriostatic Agents for the Sterilization of Water. J. V. FRÓES. Arqu. Inst. Biol. Exército (Brazil), **9**:5 ('48). In tests on the efficiency of various filters for the disinfection of pold. water the most satisfactory results were obtained with filters impregnated with silver salts. An AC filter impregnated with mercury salts was also very effective but the filtered water contained toxic concns. of mercury.—*W.P.A.*

Industrial Applications of Sodium Chlorite and Chlorine Dioxide. KEITH S. MACLEOD. Can. Chem. & Process Ind., **34**:8:640 (Aug. '50). ClO_2 employed in more than 150 Can. and U.S. munic. for destruction of taste and odors due to phenols, algae, org. matter, industrial wastes, etc. Bactericidally at least equal to Cl. Does not react with NH_3 and amines as does Cl and, therefore, not dissipated in such side reactions, free residual persisting throughout distr. system. At least 1 chem. plant treating phenolic wastes with ClO_2.—*R. E. Thompson.*

Low Iodine OK'd as Disinfectant. Chem. Eng. News, **28**:1895 ('50). As the result of a joint Army-Navy project, a committee of the Natl. Research Council recommends that a compd. capable of liberating free iodine in concns. of 8 ppm. be used for the purif. of drinking water by troops in the field.—*Iodine.*

Chemistry of Chlorination of Drinking Water Containing Ammonium Salts. S. A. FRIDLYAND. Gigiena i Sanit. No. **7**:5 ('50). When water, buffered by a phosphate buffer to pH

(*Continued on page 56*)

(*Continued from page 54*)

7–7.1, is treated with NH_4Cl and is then chlorinated, the changes (chem.) that take place in the nature of the linkage of Cl during the process can be followed by titrations (to methyl orange) and by iodometry. The Cl taken up until the uptake curve shows a sharp downward break is the chloramine Cl; Cl taken up after the break is free Cl. The concn. of the NH_4 salts is important, as dil. solns. require more than the theoretical amt. of Cl, and only in the presence of considerable concns. of the NH_4 salts does the Cl requirement (Cl:N ratio) approach the theoretical values. The change is quite apparent at a concn. of somewhat above 1 ppm. N. The concns. of Cl commonly used for water treatment lie in the region of the existence of the chloramine type exclusively.—*C.A.*

Symposium on the Sterilization of Water. (B) Chemical Aspects of Chlorination. A. T. Palin. J. Inst. Wtr. Engrs., **4**:565 ('50). A new analytical procedure developed to study the formation and decompn. of chloro substituents of NH_3 in water. Monochloramine, dichloramine, NCl_3, and some mixts. of these compds. may be formed. These may be stable but especially with excess of Cl may decomp. giving N and small amts. of nitrate. NCl_3 may be formed even with pH values up to 8. **(D) Other Processes With Special Reference to Ozone.** M. T. B. Whitson. J. Inst. Wtr. Engrs., **4**:600 ('50). Ultraviolet light, catadyn Ag, and ultrasonics have been used experimentally but on no considerable scale. Ozone has definite place in water purif. Accounts of its use confusing; methods of production various. Bacteriol. removal complete. Filtration improved. Color reduced except with Mn. Taste and odor improved.—*C.A.*

MISCELLANEOUS

The Determination of Small Amounts of Cyanide. W. G. Foyer. S. Af. Indus. Chem. **3**:53 ('49). Four methods are described for the detn. of small amounts of cyanide in water. In each method the cyanide is first distilled off into an absorbing solution so that double and complex cyanides, which may also be responsible for poln., are included in the detn. If sulfides are present they should first be removed by pptn. with lead carbonate, and strong oxidizing agents should be absent during distn. to prevent conversion of cyanide to cyanate and the decomposition of thiocyanate. The Prussian Blue method is not very sensitive and is unsuitable for concns. of cyanide of less than 1 ppm., but it is specific for cyanides. The silver cy-

(*Continued on page 58*)

(Continued from page 56)

anide method, based on comparison with standards of the opalescence formed when silver nitrate is added to solutions containing cyanide, will det. 1 part of cyanide in 5 million parts of water. The ferric thiocyanate method, which is also colorimetric, is specific for cyanides but, as the color fades quickly, the test is not very reliable. In the fourth method, phenolphthalein, in the presence of cyanide and a copper salt, is oxidized to phenolphthalein in alk. soln., giving a characteristic red color. The method can be used for concns. as low as 1 part in 50 million. All these methods can be adapted for detg. hydrogen cyanide in the atmosphere.—*W.P.A.*

New Test for Free Chlorine or Bromine. R. F. Milton. Nature (Br.) **164**:448 ('49). A method for the detn. of traces of free chlorine in water is based on the reaction of free chlorine and cyanides to form cyanogen chloride. The cyanogen chloride is allowed to react with pyridine, or a pyridine derivative, to form a quaternary compd., which on condensation with aromatic amines produces di-anil derivatives with an intense red color. This color can be compared visually against standards or measured photoelectrically. Free bromine is the only substance which reacts with cyanide in the same way as chlorine.—*W.P.A.*

The City of Sheffield's Redmires Filter Station. Anon. Wtr. & Wtr. Eng. (Br.) **54**:141 (Oct. '50). Battery of mechanically agitated pressure filters installed in '10 to deal with demand of 1.2 mgd. (Imp.). Sanction obtained in '47 to proceed with completely new filter station with yield of 3.6 mgd. (Imp.). It was decided to separate filter shells from control and machinery room to isolate cold surface areas with attendant condensation

(Continued on page 60)

(*Continued from page 58*)

from part of bldg. in continuous use. Step construction economized in excavation and foundation work and gives height, light and impression of spaciousness to "business end" of bldg. Seven 8′ diam. by 27′6″ horizontal pressure filters are installed, each rated at 21,400 gph. (Imp.). Duplicate concrete alum tanks, asphalt lined, and duplicate mild steel lime vessels are provided. Chemical dosing is automatically controlled. Central control panel, fluorescent illuminated, houses pH recorder, main rate of flow recorder and integrator, wash water rate of flow recorder and integrator, wash water storage tank depth indicator and pressure gages.—*H. E. Babbitt.*

Measurement and Analysis of Suspended Sediment Loads in Streams. M. E. Nelson & P. C. Benedict. Proc. A. S. C. E., **76**:31 ('50). Since 1939 an interdepartmental committee of U.S. Gov. has been making intensive studies on methods and instruments for detg. suspended sediment in streams. The requirements of an ideal sampler are summarized. A study of samplers which have been used in the past showed that all samplers in current use violated one or more of the basic principles of accurate sampling of sediment. These samplers included those designed to take instantaneous samples and those for sampling over an extended period either at one point (point-integrating type) or while the sampler is lowered and raised through the water at a uniform rate (depth-integrating type). Samplers were designed by the committee to correct undesirable features noted in the earlier models. The depth-integrating sampler, known as US D-43, has a streamlined body with horizontal and vertical tail nanes; the water enters the sampler through interchangeable nozzles varying from $\frac{1}{8}$ to $\frac{1}{4}''$ in diam. The point-integrating sampler, US P-46, is similar in shape to US D-43, but has an air chamber with a vol. of 5 × that of the sample container to which it is connected with tubing and passage through a spring valve. This equalizes the pressure of air inside and water outside the container and prevents a sudden inrush of water when the nozzle is opened. This sampler, while originally designed for point integration, can also be used for depth integration. To analyse the size of the particles in suspension, the bottom-withdrawal tube was developed. This is a graduated glass tube, with an outlet at the bottom, in which the sample is uniformly dispersed and then allowed to settle. Fractions of the sample are withdrawn from the bottom at intervals corresponding to the time required for particles of given sizes to settle throughout the length of the column. Each fraction is dried, the weight of the accumulated sediment is detd. and the weight of sediment of the same concn. that would remain in the suspension is calcd., a slight correction being required as the height of the column decreases. From these data a curve can be drawn and a tangent from this to the ordinate scale will show the amount of material in the sample which is smaller in size than the size represented by the corresponding time abscissa at the point of tangency. It is necessary to take variations of temperature into account, as these affect the rate of settling.—*W.P.A.*

Recent Developments in Water-Supply Forecasting From Precipitation. M. A. Kohler & R. K. Linsley. Trans. Am. Geophys. Un., **30**: 427 ('49). The techniques evolved by the U.S. Weather Bureau for forecasting water supplies from pptn. described. This method can also be used

(*Continued on page 62*)

(*Continued from page 60*)

for interpolating or extrapolating stream-flow records and for evaluating water resources. As a long period of time is involved, time trends in the data must be taken into account. The authors discuss the downward trend of run-off in the Colorado River basin in comparison with the pptn. observed. *W.P.A.*

A Shallow Impounding Reservoir as a Source of Water Supply. EMIL WINTER. Gaz, Woda i Tech. Sanit. (Poland), **24**:182 (May '50). Choice of site should be based upon sanitary and hygienic as well as hydrologic and hydrogeologic considerations. Forest areas more suitable than populated or highly industrialized areas. Effect that marine and littoral plant life may have on oxygen considered. Suggestion made that opinion of biologist necessary to det. which plant life should be removed, which remain. If found in reservoir, polysarobic forms should be viewed with alarm since indicative of poln. To destroy algal forms in reservoir, use made of $CuSO_4 \cdot 18H_2O$. Presence of fish and waterfowl not favored by author but decision for their presence should be left to biologist. Reservoir should be of sufficient size to provide supply for 2 dry yr. in succession. Depth governs capac. as well as temp. of water; shallow reservoirs allow more reaeration. Lower strata of reservoir generally not as clean as upper layers. Suggestion made to take water from 2 levels depending upon day and time of year. Need for control area around reservoir to decrease possibility of poln. indicated. Continuous control by

(*Continued on page 64*)

(*Continued from page 62*)

chem., phys. and biol. anals. should be required.—*C. P. Straub.*

Forecasting Water Works Needs in Poland. Włodziemierz Skoraszewski. Gaz, Woda i Tech. Sanit. (Poland), **24**:401 (Nov. '50). Cities and rural areas in recovered western territories quite adequately served by water works. Greatest needs in central portion of country and in rural areas. Present pop. of Poland about 24 million, with about ⅓ urban and ⅔ rural. In yr. 2000, with total pop. of about 40.7 million foresee reversal with about 60% urban and 40% rural with change to industrial-agricultural economy instead of agricultural-industrial as now. Variable rate of annual growth used during period starting with 1.25% in 1950 and reducing by increments to 1.0% in 1975 and at 1.0% thereafter. Rural pop. will remain substantially constant throughout entire period ranging from 14.7 to 16.3 million. During the next 50 yrs. 50% of the rural pop. will be served by water works to supply 100 l./capita/day. In cities 150 l./capita/day will be available. Present rate of water production about 400 million metric tons/yr. or about 5 times max. production of single industry—coal mining. In yr. 2000 will have to produce about 1.9 bil. metric tons/yr. Total cost including sewers, amortization and maintenance, estd. at 3.86 bil. dollars (based on 1938 evaluation).—*C. P. Straub.*

The Alpine Karst: A Natural Water Reservoir. Gustave Abel. Gas, Wasser, Wärme, **IV**:259 (Nov. '50). Karst formation in the alpine lime-

(*Continued on page 66*)

(Continued from page 64)

stone regions has taken place throughout the geological ages. Water supply from these eroded and corroded limestone regions depends on rainfall, snow deposits and ice formation in the caverns. Normal rainfall on the plateau appears within 6–8 hr. at its foot. Heavy rains cause increased flow from springs within 4 hr. Natural storage of rain water is possible only to a small extent within the capillary fissures of the limestone. Snow deposits on the plateau, which melt very slowly during the winter, are responsible for torrents of water from the springs during the thaw. Some snow, remaining in cracks and crevices, becomes a water source until July. Prevailing winter temperatures within the caverns during the spring thaw effect the formation of large ice deposits which become a water source in the summer and last through October. In November rains take up their responsibility for water supply. Prevention of dumping garbage and refuse into the cracks and crevices of the plateau is necessary to elim. poln. Flows from the karst springs are usually ample but erratic and frequently contain considerable turbidity. Waste of water occurs during heavy rains and thaw. The use of the space within the mountain as a reservoir to control the flow by means of dams is suggested.—*P. K. Mueller.*

OTHER ARTICLES NOTED

Recent articles of interest, appearing in American periodicals, are listed below.

Experience Shows Laying Mains in Alleys to Be Unwise. A. H. LABSAP. W. W. Eng. **103**:206 ('50).

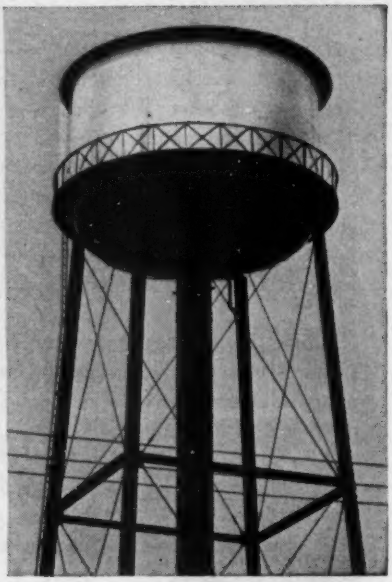
The Filter's Operating Story. Eng. News-Rec. **144**:15:34 ('50).

Twice As Much Water For Cincinnati. R. E. DUHME. Eng. News-Rec. **143**: 12:30 ('49).

Progress Report On Chlorine Dioxide. R. N. ASTON. J.N.E.W.W.A., **64**:1 ('50).

Critical Review of Literature on the Toxicity of Industrial Wastes and Their Components to Fish. 1. Alkalies, Acids and Inorganic Gases. PETER DOUDOROFF & MAX KATZ. Sew. & Ind. Wastes, **22**:1432 ('50).

Literature Review on the Occurrence and Survival of Enteric, Pathogenic and Related Organisms in Soil, Water, Sewage and Sludges, and on Vegetation. 2. Animal Parasites. WILLEM RUDOLFS, LLOYD L. FALK & ROBERT A. RAGOTZKIE. Sew. & Ind. Wastes, **22**:1417 ('50).



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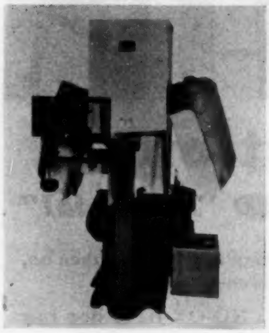
(*Continued from page 16*)

Rainmakers of America, Awake! While you've been piddling around with decadent democratic dry ice and imperialistic iodide, solid Soviet scientists have developed "improved types of electronic machines for artificial rain," which can be used—even if you don't want rain—to "mechanize the application of fertilizers and chemical substances for fighting weeds and vermin." As a matter of fact, out of one of those fair weather machines must have come Tass news agency's announcement of last week that did another Russian rollback to invent television by the banks of the Volga in 1906. No wonder the Czar got out!

Dante E. Broggi, formerly vice-president and general manager of Neptune Meter Co., is succeeding John H. Ballantine as president of the company. After 17 years as president, Ballantine is becoming chairman of the board of directors.



An improved Fluoridizer for feeding fluoride chemicals has been developed by Omega Machine Co., 345 Harris Ave., Providence 1, R.I. The feeder, known as Model 47-A (at left), is scale-mounted and offers large hopper capacity, dustless filling, and low filling height. Frequent filling is minimized by size of the hopper, which can hold two 100-lb. bags or one 125-lb. drum carton. Dust is minimized by opening the bags at the bottom of the hopper, thus avoiding the fall of the chemical through the air.

J. Don Carpenter, vice-president of Gannett, Fleming, Corddry and Carpenter, Harrisburg consultants, has been elected president of the Pennsylvania Society of Professional Engineers.

(*Continued on page 70*)

(Continued from page 68)

David E. Moulton, clerk and attorney of the Portland Water Dist., died suddenly at his home in Portland, Me., on April 21. He was 79 years old.

He had been president of the Maine Water Utilities Assn. from its inception in 1925 until 1950, when, at its 25th anniversary celebration, he was elected president emeritus.

John M. Hopwood, chairman of the board of Hagan Corp. and its subsidiaries, including Calgon, Inc., died on June 8 at Vero Beach, Fla. He was 67 years old.

Robert M. Morgan, director of water for Fairmont, W.Va., died on April 17 after an illness of some duration. He had previously served as street commissioner for the city and sealer of weights and measures for the county.

The Ford Meter Box Co., after 35 years in its former location, has moved to new and larger quarters on U.S. Route 24, still in Wabash, Ind.

(Continued on page 72)

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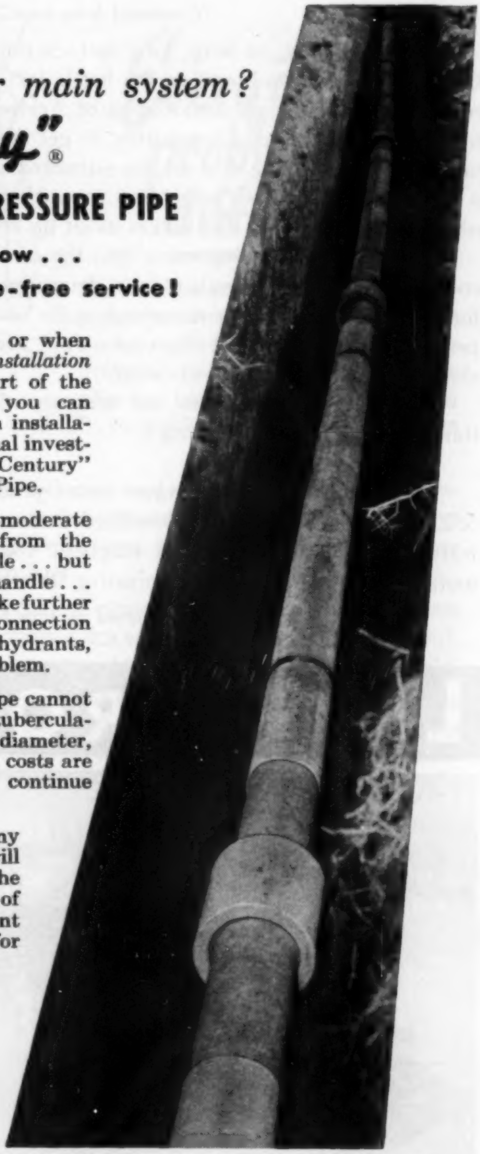

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COMPANY · AMBLER · PENNSYLVANIA

(Continued from page 70)

Weaned now, at long, long last, is the U.S. Senate, which for all these years has been bound to the bottle for its water. It took the water consciousness and conscientiousness of Aridzona's Senator Hayden, chairman of the Senate rules committee, to get the senior lawmakers at last on tap. To us, of course, it's not the estimated savings of $37,000 per year— a mere quarter mill per populee— as much as the consequent recognition of public water supply that makes us sit up and take notice.

What brought spring water into the senators' offices in the first place couldn't be at all remembered or determined when the habit was thus forsworn. What kept it there was quite obviously the $385 per senator per year that constituted the cost. And even that would be considered cheap if they'd only drink the stuff.

Ah well! Weaned now, our senators will soon be adult about everything. We should live so long!

A Norlantic Torrent water meter produced by George Kent, Ltd., of London, has been specially modified to meet Canadian needs. The meter features low head loss and a magnetic coupling for transmitting rotor motion to the register, thus eliminating the necessity for packed glands.

(Continued on page 74)

(*Continued from page 72*)

Rain on the roof is as nothing compared with the lot of a lot of Italian families these days. "Public water supply as the roof" has been their situation since postwar joblessness reduced them to making their homes in the archways of Rome's ancient aqueducts. For miles along famed old Appian Way, for instance, aqueduct arches provide no-rent housing with none of the modern conveniences. And if some of the more elaborate archways are flanked by flower and vegetable gardens to bright the bleak, dank stone, none are at all plumbed and none can even tap its top for running water. As a matter of fact some of the archers recently asked authorities for permission to drill water supply holes at least every third or fourth arch, but permission was immediately not granted, all officialdom eschewing the idea of such a holey Roman empire and shuddering at the thought of consequent fallen arches.

So the subaqueductous continue to beg water from neighboring farmers and work when they can at a laboring wage of $1.50 a day, crediting the water over their heads for helping keep their heads above water.

Eugene A. Hardin, formerly of the Dept. of Public Works, Philadelphia, has joined the staff of Parsons, Brinckerhoff, Hall & Macdonald, New York consultants. He will be a member of the water supply and sewerage team headed by G. Gale Dixon. His previous consulting experience was with Black & Veatch of Kansas City and Consoer, Townsend & Quinlan of Chicago.

A new compound meter manifold unit has been introduced by Rockwell Mfg. Co. to permit meter maintenance without shutting off service or working after closing time. The assembly consists of two single-register compound meters in combination with four cone valves and two 8-in. reducing manifolds. The arrangement permits taking one side out of service at a time, for meter removal, replacement or—through use of a special test plug in the meter body—testing in place.

(*Continued on page 76*)

(Continued from page 74)

A sort of scientific umpire is our friend "Dr. Mack" MacKenzie, technical director of the American Cast Iron Pipe Co. At any rate, that's what he seemed to add up to in the brief biography printed in *Chemical & Engineering News* on the occasion of his winning the 1951 Herty Medal of the Georgia State College for Women's Chemistry Club. What causes our characterization is Dr. Mack's reportedly outstanding sense of pitch and his high proficiency in science. Thus, in describing its cover boy, *C&EN* of May 21 pointed out that that combination of virtues enabled him to discover the direct relationship between the natural frequency of a cast-iron test bar, when the metal is struck by a mallet, and the bar's modulus of elasticity. A lot of good that would do him at the Dodgers' Ebbets Field.

Hector P. Boncher, general manager of Dresser Mfg. Div., Bradford, Pa., has been elected vice-president of the parent organization, Dresser Industries, Inc.

Walter N. White and William F. Guyton have opened a consulting office as ground water hydrologists. Their office is located at 10 Mississippi Ave., Silver Spring, Md.

(Continued on page 78)

When they're in service 100 Years...
THEY'LL STILL BE FULL OF LIFE!
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Cast Iron Pipe & Fittings
Long life is the real test of pipe line economy. Clow Cast Iron Pipe and Fittings give you that long life service... for a *century and more*... and offer the surest way to keep your municipal water supply system at peak efficiency—now and in the years ahead!
City officials throughout the nation have long ago *proved* that it actually costs less to use Clow Cast Iron Pipe and Fittings. They have found that after installation, practically no maintenance, repair or replacement is necessary. So prove to *yourself* that Clow Cast Iron Pipe and Fittings will be a wise investment of public funds!
Bell and Spigot Joint
The common bell and spigot type of cast iron pipe joint with standard water bell... for poured and calked lead make up.
Clow Mechanical Joint
A time-saving, easily installed mechanical cast iron pipe that reaches the job with all joint materials complete.
Flanged Joint
For exposed pipeline work. Flange dimensions and drilling conform to requirements of A.S.A. Class 125 for flanged fittings and valves.
Clow Cast Iron Pipe Fittings
All types of Clow Cast Iron Pipe Fittings are offered in straight and reducing sizes for use with Bell and Spigot Joint, Mechanical Joint, and Flanged Joint cast iron pipe.
Bell & Bell One-Eighth Bend
Mechanical Joint 90° Elbow
90° Standard Flanged Elbow
Special Fittings
Clow Foundries are well equipped to produce your special fittings promptly and accurately, to meet particular requirements, and to solve unusual installation problems.
Write for Price and Delivery
Clow Cast Iron Pipe is centrifugally cast—in sizes from 3 to 24", in 18' lengths, and for working water pressures to meet your requirements. Meets Federal Specifications WW-P-421 for Bell and Spigot Cast Iron Pipe for Water. Clow pipe can be easily cut in the field if needed, and drilling and tapping it for services results in superior threads and perfect connections.
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CAST IRON

(*Continued from page 76*)

A floodlight in no uncertain terms was one of Pittsburgh's street lights the other day when a water main burst directly below the hollow metal pole on which the light was mounted. Out of every hole and joint in the pole, beginning some 10 ft. above the street, issued a fountain or flood that doused pedestrians and made autoists roll up their windows in driving by. Water always makes a splash!

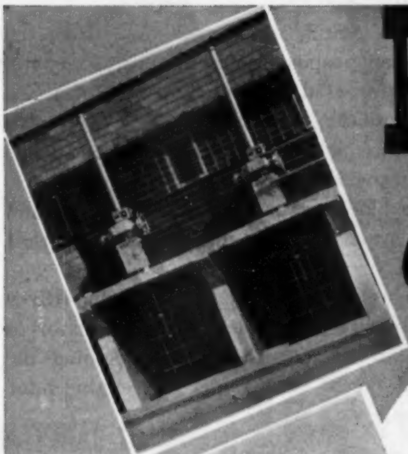
Lewis I. Birdsall, technical service representative for General Chemical Div., Allied Chemical & Dye Corp., has retired after 29 years of service with that organization, during which he travelled extensively, specializing in dealing with the coagulation problems of filter plant operators. Prior to his association with General Chemical, he had been chief chemist of the State Water Survey in Illinois and superintendent of filtration at the Columbia Heights Plant for Minneapolis, Minn.

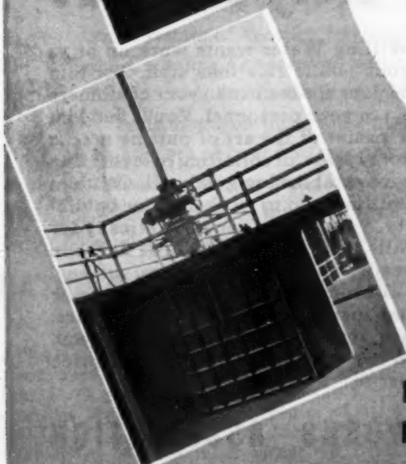
A dry chemical feeder, known as the Chemizer, has been introduced by Omega Machine Co., 365 Harris Ave., Providence, R.I. It has been designed to feed and weigh from 5 to 5,000 lb. of filter alum per hour, and do this accurately and continuously. A five-figure register records pounds fed, and alarms for over- or under-feeding are standard equipment.

What Price Water? was our question last May (P&R, p. 12) when we reported that a Baltimore cannery had started putting up $10\frac{1}{2}$-oz. supplies of drinking water for the civilian market. Nineteen cents—oops, fifteen cents now—is the answer at Macy's New York, where the product is being sold to campers, boaters and sundry other pessimists—Lifesaver brand, too! What can't you do with a can opener these days?

Ralph L. Carr has been appointed manager of the technical service department, Mathieson Chemical Corp.

(*Continued on page 80*)





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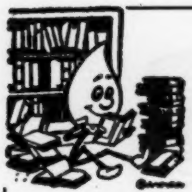
The ocean notion is still on tap. "Still," we say, because that's the instrument Interior Secretary Chapman proposes to employ in converting sea water to drinking water in two proposed experimental plants on the Pacific Coast and one in the metropolitan New York area. All that's necessary now is Congressional approval. All, we say, because we've already convinced our own Representative that we can do the job ourselves, easily, with a deep-freeze unit and a blow torch—icing the salt away and then melting the desalted ice. You want to buy some stock? Watered!

Kenneth S. Watson, formerly assistant director of the Ohio River Valley Water Sanitation Commission, has been appointed coordinator of industrial waste treatment for General Electric Co. Before joining the Ohio River organization he had been executive secretary and engineer for the West Virginia Water Commission.

A two-year modernization and expansion program has just been completed by Diamond Alkali Co. at its electrolytic chlorine and caustic soda plant at Army Chemical Center, Md. Production of chlorine at the plant, which has been leased by Diamond from the government, is being increased by 30 per cent.



The Reading Meter

Water—or Your Life. *Arthur H. Carhart. J. B. Lippincott Co., Philadelphia (1951) $3.50*

One more in the series of books sounding a call to arms to the public to preserve and safeguard our water resources before it is too late, this volume adds an aggressive bugle note to the chorus. Although the contrived, popularized style is fairly wearing, there is much interesting background material which shows more thorough research than has been performed by other authors who also cited historical calamities to cultures resulting from misuse or lack of water. As a conservationist, the author has an extreme bias toward the forestry and wild-life aspects of water management which appears to embitter him toward other uses and demands for water. In that respect he himself offers evidence of the great care which must be exercised by those attempting to deal with the problem, in order to obtain a balanced, comprehensive viewpoint.

Manual for Water Works Operators. *Texas Water Works and Sewerage Short School, State Department of Health and Texas Water & Sanitation Research Foundation, Austin, Tex. (3rd ed., 1951)*

This new edition of a well known and useful manual has been revised to take into account many changes in water works knowledge and practice which have been introduced since the last edition was published in 1943. A series of chapters compiled by various authorities cover the range of topics with which the practising water works man must be familiar, from raw water supplies through the pumping, storage, measurement and purification processes. Chapters on corrosion, industrial water supply, construction and other financing and design round out the scope of the volume. In addition, regional interests are met by a chapter on health department requirements (principally in Texas) and by an appendix on certification of operators. Other useful appendixes offer data on the U.S. Public Health Service Drinking Water Standards, laboratory equipment and supplies, pol-

(*Continued on page 84*)

The Reading Meter

(*Continued from page 82*)

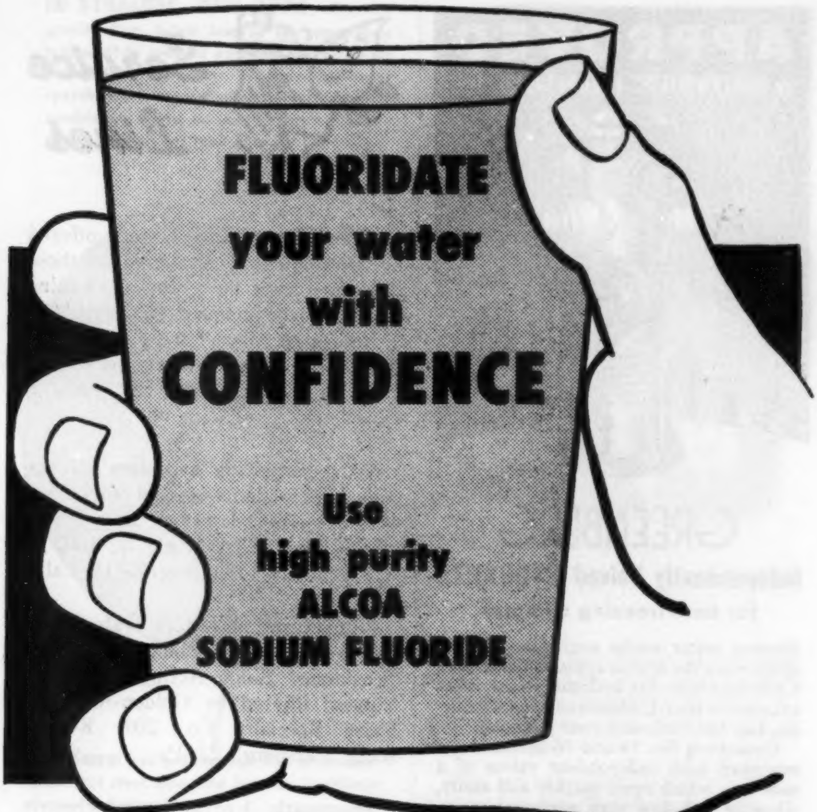
lution control regulations, fluoridation, emergency operation, safety, sources of standards, and books and other publications. It is unfortunate that greater care was not exercised in compiling the last two sections, for the section on standards repeatedly gives the source of A.W.W.A. specifications either as the issue of the Journal in which they first were published—thus disregarding the many revisions which have since been made in many of them, or else as *Water Works Practice*—a volume which has been out of print for a number of years. The section on books similarly refers to the unavailable (and outdated) *Water Works Practice* manual, and also to the out-of-print *Handbook of Cast Iron Pipe,* to name only two. In general, however, the volume offers a valuable review of essential information.

Architectural Graphic Standards. *Charles George Ramsey & Harold Reeve Sleeper. John Wiley & Sons, New York (4th ed., 1951) $10*

The fourth edition of an architect's standby will also be found useful by engineers, draftsmen and contractors. More than five hundred oversized pages of drawings give construction details of most units found in ordinary and even many types of specialized building. Drawings and dimensions of cabinets, furniture, tools and furnishings for which space allowances must be made are also included. The volume is thoroughly indexed.

Review of Current Research and Directory of Member Institutions. *Engineering College Research Council, American Society for Engineering Education, Room 7-204, 77 Massachusetts Ave., Cambridge 39, Mass. (annual; 1951) $2.25*

This useful survey covers more than 5,200 research projects being conducted at a cost of over 50 million dollars at 91 engineering schools in America. In addition to complete research project titles and an index of subjects, the volume contains information on the policies, personnel and expenditures for research at the various schools. Persons contemplating research projects will do well to consult this volume to avoid duplication and, perhaps, be guided toward a rewarding exchange of information.



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Service Lines

A booklet on the services offered by Dowell, Inc., is offered to those concerned with the chemical cleaning of industrial equipment. Entitled "Cut Maintenance Costs," the 8-page illustrated bulletin is available from Dept. P of the company, Box 536, Tulsa 3, Okla.

Valve actuating cylinders for the operation of gate, cone and other types of valves, are described in a leaflet offered by Ledeen Mfg. Co., 1602 S. San Pedro St., Los Angeles 15, Calif.

Nonreturn or check valves are the subject of a bulletin entitled "Cushioned Single-Acting Nonreturn Valves" offered by Golden-Anderson Valve Specialty Co., 2091 Keenan Bldg., Pittsburgh 22, Pa.

Pneumatic, hydraulic and electric operated Nordstrom valves are extensively described in a 40-page bulletin, V-214, issued by Rockwell Mfg. Co., Pittsburgh 8, Pa.

"Dresser Couplings," a lavishly illustrated, 34-page catalog devoted to Style 38 couplings and Style 40 long sleeves for joining steel and cast-iron pipe has just been issued. Copies may be obtained from the Dresser Mfg. Div., Bradford, Pa.

Books published by Interscience Publishers, Inc., 250 Fifth Ave., New York 1, N.Y., are listed and described in the publisher's 1951 catalog, available on request.

(Continued on page 88)

(*Continued from page 86*)

The Metallizing Engineering Co., 38–14 30th St., Long Island City 1, N.Y., has assembled a portfolio of bulletins dealing with metal spraying techniques for corrosion prevention on a variety of iron and steel structures. Specifications, descriptions of procedure and illustrations are included.

Piping fabrication and erection is the subject of a 24-page booklet issued by Dravo Corp., Neville Island, Pittsburgh 22, Pa. The Bul., No. 1700, is being offered as a description of the firm's facilities for engineering, fabricating and installing industrial piping.

Taylor Forge Catalog 501, offering descriptions of nozzles, welding necks and large diameter flanges, is being offered to those interested in pressure vessel work. The volume also contains TEMA standards and "Modern Flange Design," which is also available separately as Bul. 502. Inquiries should be addressed to Taylor Forge & Pipe Works, Box 485, Chicago 90, Ill.

A new catalog of main-line metering equipment, known as Bul. 311, has just been issued by Sparling Meter Co., 945 N. Main St., Los Angeles 54, Calif. Among items listed for the first time are a saddle mounting for reinforced concrete pipe and a level and open-flow indicator.

"The Phoscote Process" is the title of an 8-page booklet just issued by Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill., to describe a process for removing mill scale from steel plates and shapes by immersing them in baths of sulfuric acid, wash water and phosphoric acid. A clean dry surface is provided, coated with iron phosphate, which improves the bond between the steel and the prime coat of paint. The latter is applied while the metal is still warm from the final bath.

Index of Advertisers' Products

A complete Buyers' Guide to all water works products and services offered by A.W.W.A. Associate Members appears in the 1950 Membership Directory.